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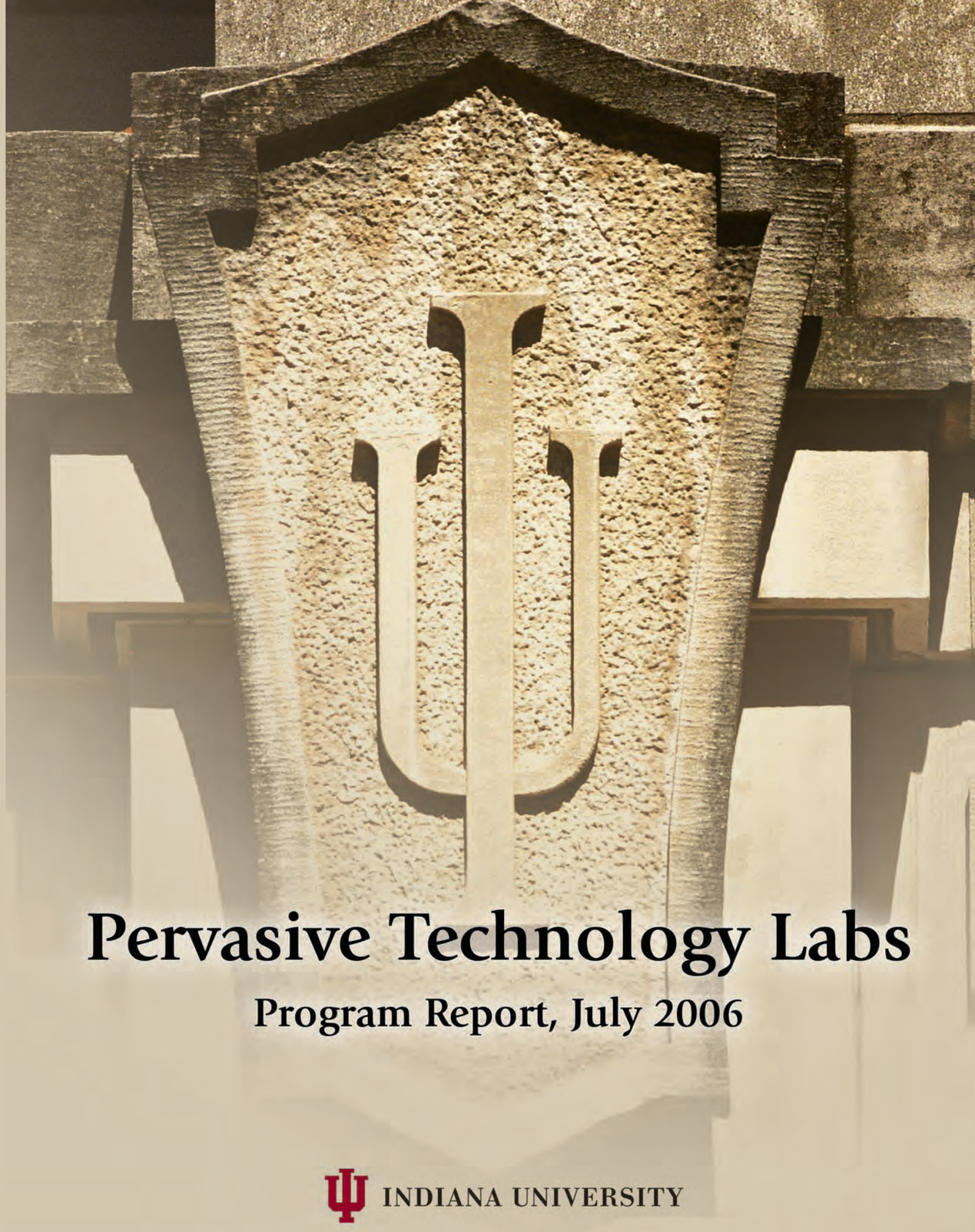
Pervasive Technology Labs Program Report, July 2006



Pervasive Technology Labs

Program Report, July 2006

INDIANA UNIVERSITY

pervasivetechnologylabs
AT INDIANA UNIVERSITY

Report to the Lilly Endowment, Inc.
Grant Number 1999 2280-000

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I. EXECUTIVE SUMMARY AND INTRODUCTION

In 1999, the Lilly Endowment, Inc., awarded a grant of $29,976,162 in support of the Indiana Pervasive Computing Research Initiative (IPCRES).

Key goals of this grant were to:

- *create what is now called Pervasive Technology Labs (PTL), a group of six advanced information technology and computer science research and development laboratories;*
- *accelerate the development of the IU School of Informatics;*
- *educate and retain an outstanding 21st-century workforce in the state of Indiana;*
- *aid economic growth in the state of Indiana through technology transfer from Pervasive Technology Labs and via direct investment from the PTL Capital Investment Fund in high-tech startups in Indiana.*

Development of Pervasive Technology Labs has been steady since 1999—and activity and successes have accelerated in the last two years. As of June 30, 2006, Indiana University has made significant progress toward achieving the milestones set out in the original 1999 proposal. The milestones identified in the initial report have either been achieved, or significant progress has been made toward achieving them. A key summary of accomplishment is as follows:

- Pervasive Technology Labs has produced a grand total of 358 publications since inception.

- Pervasive Technology Labs has enhanced faculty productivity through the PTL Fellows Program. Initiated in 2003, the program provided modest grants to eight faculty members to support new and innovative projects. Summary project and accomplishment reports by the PTL Fellows appear in the current report. The PTL Fellows Program supported 60 scholarly publications and presentations by PTL Fellows during their tenure and PTL Fellows secured 18 related grants totaling nearly $8 million.

- A total of 9 graduate students have completed master's degrees and a total of 11 have received Ph.D. degrees via research conducted within PTL.

- PTL has brought in a grand total of $17,772,535 in external grant and contract funding since its inception, and grants secured by other subunits of Indiana University in collaboration with or via leverage of PTL total $58,295,973. The total economic impact of PTL on Indiana University grant and contract funding, direct and indirect, totals more than $76 million.

- PTL has disclosed more than 30 new inventions to the Indiana University Research and Technology Corporation, including two patent applications. PTL has released a total of 37 open-source software packages, and offers a total of 56 online services. (For a complete listing, please see the complete 78-month report at www.pervasive.iu.edu.)

- PTL has given presentations, demonstrations, and tours to thousands of students, educating them about careers in advanced technology and encouraging them to consider those careers. Similarly, information disseminated via public relations and press channels has helped inform many Indiana residents about new innovations in advanced technology created by PTL, and about the role PTL has within the state.

- The IU School of Informatics is off to an impressive start—with a current enrollment of over 1,000 undergraduates and over 400 graduate students system-wide. Forty-eight percent of IU School of Informatics graduates have stayed in the state of Indiana for their professional careers.

During the reporting period of January through June of 2006, the individual Pervasive Technology Labs have made significant progress, as follows:

- The Open Systems Lab (OSL) continues its primary efforts to develop open-source tools to support next-generation cyberscience. Most notably, OSL's large-scale parallel computing tool, Open MPI, remains an important and high-profile project. Open MPI is instrumental in IU's ability to obtain maximum performance from their new supercomputer, Big Red, which was recently named among the world's fastest. Many news items about the software's role in facilitating Big Red were recently highlighted in a variety of media outlets.

- The Advanced Network Management Lab (ANML) continues research in the area of advanced cybersecurity and forensics. One notable project for the period is their development of distributed Botnet tracker software. "Botnets" are computers infected by a robotic virus under the control of a central authority and are a major problem today in Internet security. The lab, along with project lead University of Michigan, anticipates receipt of a new award from the Department of Homeland Security (DHS) to continue work on the project in the coming period.

- The Community Grids Lab (CGL) had a highly successful period, both in intellectual output (producing 23 publications and 46 presentations) and in securing several large, high-profile funded projects. The lab received an impressive three awards from Microsoft Corporation to support their work in various research areas, and a CGL spin-off company, Anabas, in partnership with the lab, has also been very successful in obtaining grants from the federal government and the State of Indiana in recent months. CGL has many important ongoing projects. One noteworthy activity is their continued and increasing involvement in improving the cyberinfrastructure for Minority Serving Institutions.

- The Visualization and Interactive Spaces (VIS) Lab has expanded its ongoing efforts in developing a variety of visualization tools, with a special interest in visualization of environmental research and education. The VIS Lab, in collaboration with IUPUI's Center for Earth and Environmental Science (CEES), received an award during theperiod from Veolia Water, Indianapolis, to start a program called Discovering the Science of the Environment (DSE.) The program aims to provide learning opportunities for children and families and to provide resources for educators in the discipline of environmental science. The lab also continues its work on VisPort, a system to support access to high-performance visualization capability via the Web.

- The Scientific Data Analysis (SDA) Lab continued its work in applying state-of-the-art information technology towards advancing science research, with a special interest in life sciences and chemistry applications. The SDA Lab is now hosting three new online services with the Center for Computational Biology and Bioinformatics at IUPUI and the lab, in collaboration with a research group in the Department of Chemistry at Purdue, continued to develop and promote a software tool for analyzing nonlinear optical properties of molecules. SDA Lab researchers also renewed a collaboration with the Biocomplexity Institute at Indiana University to develop an open-source toolkit for modeling cellular tissue.

- The Knowledge Acquisition and Projection (KAP) Lab advanced its work on scientific instruments and sensors, co-organizing a workshop on the topic and participating in several important international projects. The lab worked with Australian collaborators on sensor network technologies to support a project that examines environmental impacts on lakes and coral reefs. KAP Lab researchers are also working with a group from Turkey to study policy and funding patterns for scientific research done by international collaborators, which they expect to expand to include additional countries and regions in the coming months.

Intellectual and artistic productivity. During the reporting period, PTL published 38 papers in peer-reviewed journals, disclosed two new inventions, released 11 new open-source software packages, and provided eight new online services for the U.S. research community. (For a complete listing, please visit www.pervasive.iu.edu.)

Creating a highly trained and diverse 21st century workforce for Indiana. During the reporting period, PTL launched a new Community Outreach Program. A key success in the program was a display of the Indy Robotics Vehicle sponsored by the Advanced Network Management Lab at the 2006 Intel International Science and Engineering Fair held in Indianapolis in May. An estimated 2,000 students visited the display, and approximately 800 students received a photograph of her/himself in front of the IRV.

Educating the citizens of Indiana and beyond. A critically important part of the overall effort to build a high-tech economy in Indiana is educating the citizens of the state about the value of this approach. PTL has been very productive in press releases during the current reporting period—a total of 33 press releases and articles in the popular media discussed PTL accomplishments.

External grant funding. During the reporting period, PTL was awarded a total of $1,001,681. Grants obtained by other subunits of IU via collaboration with or leverage of PTL during this award period totaled $8,338,750, for a total grant impact on the university of $9,340,431. Due to the national funding situation for the sciences, success rates on grant proposals are at a particularly low point. As a result, PTL has been very aggressive in applying for new grant funding. During the reporting period, a total of $27,797,388 in grants were newly applied for or under continuing review. (For a total listing of PTL-funded research, please visit www.pervasive.iu.edu.)

Bringing distinction to the state of Indiana. PTL has existed at Indiana University long enough to develop a significant national and international reputation. PTL is doing more than publishing many papers and bringing in many grant dollars. Over a number of years PTL has consistently done excellent work, establishing IU as a leader in many new areas of computer science and advanced computing technology. A few examples of the level of prestige now enjoyed by IU as a result of PTL follow:

- The ChemBioGrid grant was awarded to Indiana University as a direct result of the excellent reputation and level of accomplishment accrued by Dr. Geoffrey C. Fox and the Community Grids Lab. The grant has created important opportunities for innovation by the national cheminformatics community and is helping Indiana University to become a leader in this area of research.

- The Open Systems Lab is internationally recognized for the quality of its work with the OpenMPI library, which is the basis for programming many of the world's largest supercomputers. IU's Big Red supercomputer, the fastest academic supercomputer in the United States runs on OpenMPI. Dr. Thomas Sterling, a luminary working in the area of supercomputing, presented his perspective on the world of high performance computing at the International Supercomputing Conference in Dresden, Germany, this June. He made the following comment: "…watch the Indiana group. This year could be the year of OpenMPI." And OpenMPI is only one of the many projects undertaken by the Open Systems Lab. Their work in generic programming in the C language—meant to make software components truly and practically reusable—could revolutionize the entire area of scientific computing.

- The TeraGrid funds nine universities as resource providers and a small handful of universities as key technology developers. IU was funded to become a part of theTeraGrid in large part due to the distinction and involvement of Pervasive Technology Labs.

- PTL Science Director Dennis Gannon and Indiana University scientists are leading the Portals effort and workflow orchestration component for National Science Foundation's Linked Environments for Atmospheric Discovery (LEAD) project. The LEAD project makes Indiana University part of a select group of institutions working to develop and improve fundamental information technology used to study, understand, analyze and predict potentially damaging weather events.

- PTL Chief Operating Officer Craig A. Stewart received a Fulbright Senior Specialists Award that allowed him to travel to Germany to forge an important international research collaboration on high-performance-computing and the life sciences between IU and researchers at the Technische Universität Dresden.

The preceding examples all speak to one conclusion: As a direct result of Pervasive Technology Labs' activities, Indiana University has achieved considerable levels of intellectual accomplishment, importance as a generator of transferable technology, and an international reputation in several areas of advanced computer science and computing technology—all accomplishments that are without precedent at IU.

II. LAB REPORTS

II.1. OPEN SYSTEMS LAB

Andrew Lumsdaine

Director

Lab Mission

The mission of the Open Systems Lab (OSL) is to develop science and technology for computing with large-scale and pervasive hardware and software systems, to enable more productive computing and software development, and to foster economic development in the state of Indiana. Work in the OSL is motivated by the changing nature of modern information technology systems. For pervasive systems to interoperate seamlessly, standardization is needed. All pervasive systems must speak the same language. Standardization is complicated in today's market-based economy, but can arise in several ways—government mandate, industrial monopoly, or open standards, to name a few. The OSL strongly advocates the latter and is working to create open-source software tools to bring this about.

Summary of Key Lab Activities, January–June 2006

Current research projects at the OSL remain focused in five core areas:

- **Next generation programming tools and languages.** The OSL is creating tools to enable large-scale pervasive software applications. Key OSL activities in this area include continued research into the theory of generic programming as well as its practical application in programming languages, software libraries, and software applications.

- **Parallel and distributed computing.** The OSL is currently spearheading several efforts in high-performance parallel and distributed computing to improve reliability, availability, and scalability of these environments, including the Open MPI and OSCAR projects.

- **Scientific software.** As computation becomes an increasingly important tool for science and informatics, the OSL is developing tools, practices, and curricula to allow scientists and informaticians to effectively develop software while maintaining a primary focus on their research.

- **Automatic device configuration.** Recognizing the increasing number of mobile devices in use, the OSL is developing technologies for these devices to be able to configure themselves automatically, based on context and user preferences.

- **Applications.** The OSL is collaborating with several research groups at IU and elsewhere to apply our research results to other scientific projects. Collaborators include the IU BioComplexity Institute, the School of Informatics, the School of Library and Infomation Science (SLIS), and University Information Technology Services.

Research and Development Activity

The Message Passing Interface (MPI) library standard defines the most critical tools in existence for programming supercomputers. The Open Systems Lab's Open MPI Project remains at the forefront of the High Performance Computing community in research and development of a production-quality, open-source version of this important standard. Version 1.1 of Open MPI was released in June 2006 and represents a feature-complete implementation of the MPI 2.0 standard. In addition, Open MPI provides many new research-produced features and performance enhancements not previously available in an open-source MPI implementation. Open MPI enables robust scientific computing across thousands of computers, allowing scientists and engineers to focus on their work rather than the mechanics of parallel computing.

Generic programming is a concept designed to make computer application components easily reusable. OSL continues to develop technologies in support of generic programming and has developed specific extensions to the C++ programming language to directly support this important programming paradigm. In collaboration with Bjarne Stroustrup (inventor of the C++ language) and his colleagues at Texas A&M University, the OSL has submitted a proposal to the international C++ standardization committee based on our extensions. In addition to the proposal, OSL has

developed and deployed a prototype C++ compiler that supports our proposed language extensions. Although the proposal has yet to undergo a formal vote within the committee, the proposal and the compiler have been well received. It is highly likely that these language improvements will be included in the upcoming C++ standard, and thus available to millions of C++ developers within the next five years.

Scripting languages are ubiquitous in modern software engineering and are often used as the sole language for application development. However, some applications, specifically scientific and multimedia applications, often have small sections of code that require a higher level of performance than the host language can deliver. In many cases, the algorithm being optimized is simple and has a clear mapping to hardware resources. But without introducing an intermediate language, developers generally have no direct methods to implement an optimized solution. To address this issue, OSL researchers are developing a new programming approach called "synthetic programming." The synthetic programming environment includes a run-time system for synthesizing and executing high-performance instruction sequences directly from scripting languages.

A particle simulation implemented using Synthetic Programming, a high-performance programming methodology developed at the OSL.

Intellectual Accomplishments and External Funding Activity

- Four (4) new packages of open-source software were distributed by OSL during the reporting period, including: LAM/MPI, Open MPI, PSWEEP, and Boost Libraries.
- OSL had ten (10) new peer-reviewed publications appear in print during the reporting period.
- The lab gave a total of nine (9) presentations at academic meetings and conferences during the period.
- Two (2) grants were awarded to the OSL, totaling $179,648, during the reporting period, all of which flows directly into the Lab.
- Five (5) additional grant proposals totaling $1,990,217 were submitted and are under continuing review.

Educating the Residents of Indiana and Beyond

- OSL's Dr. Kay Connelly continues to serve as a faculty advisor for the group Women In Computing at Indiana University (WIC@IU) and works to support the group's nationally recognized outreach program for Indiana high schools called "Just Be." The goal of the Just Be interactive experience is to help break common stereotypes about people in computing. Participants use online voting modules to participate in polls that challenge personal stereotypes. By informing young women and men of potential careers while they are still in secondary school, Dr. Connelly and the WIC@IU group stand to increase the number of young people in Indiana who pursue careers in advanced technology.

- Dr. Connelly and WIC organized InWIC 2006, the second regional Indiana Women in Computing Conference. This conference is intended to give women who could not normally afford to attend a conference the opportunity to present their work and meet other women in the fields of computer science and information technology. InWIC2006, held February 3-4, was a joint effort with Purdue, Rose Hulman, and DePauw and was a great success, with 127 attendees.

Accelerating Economic Growth

- Veterisoft, Inc., a spin-off of the Open Systems Lab, plans to market a tool that will support and improve the collaborative development of software. Veterisoft, Inc., has completed a detailed business plan and a beta test version of the SourceHaven software development tool. SourceHaven is now available for purchase and has been sold to several customers.

- The Open Systems Lab, in collaboration with Indiana-based Progeny Linux Systems, Inc., Server Partners LLC, and TechPoint, helped found the Open Source Software for Business (OSS4B) consortium. OSL and OSS4B believe that there are tremendous possibilities for creating and expanding businesses based on open-source software. Opportunities include the potential to build commercial software products as derivatives of open-source software, or to create businesses based on the implementation and support of open-source software products. OSS4B exists for the purpose of exchanging information to facilitate such business development. OSS4B's monthly meetings include presentations and open discussions that help businesses understand the open-source movement and why it is gaining momentum, providing a forum where individuals can learn how to participate in open-source development, and how to benefit from it.

Bringing Distinction to Indiana University and the State of Indiana

In June of this year, Indiana University's new supercomputer, Big Red, was identified as the fastest among all U.S. academic institutions and the 23rd fastest supercomputer in the world by the Top500 List . The acquisition of Big Red positions Indiana University among national leaders in cyberinfrastructure capabilities and provides a tremendously valuable resource to the Indiana research community. To achieve the greatest parallel processing efficiency, IU will be using the OpenMPI implementation of the Message Passing Interface (MPI) specification. OpenMPI was created by an international consortium of several major research labs including the Open Systems Lab. OpenMPI provides especially advanced tools for taking advantage of and effectively utilizing a complex supercomputer cluster such as Big Red.

Lab Outlook, July-December 2006

For the second half of 2006, OSL will continue to conduct research and development projects in its core areas of next-generation software languages and tools, parallel and distributed computing, collaborative software development, automatic device configuration, and applications. Several of these projects are approaching (or are have reached) critical mass, requiring full-time research staff to manage and continue to grow the projects.

In their work on next-generation languages and tools, OSL researchers will continue to advance the state of the art in generic programming in particular and to transition their work as quickly as possible into the hands of practicing programmers. OSL researchers have presented several proposals to the C++ standards committee to enable improved support for generic programming, including an ambitious proposal to add first-class support for generic programming to the C++ programming language. Building on the technology they have developed for this proposal and on the widespread support that it has generated, OSL will seek to gain acceptance into the upcoming revision of the ANSI/ISO C++ standard. Over the longer term, the Open Systems Lab will be developing significant extensions and enhancements to both C++ and C# so that generic programming can be even more fully supported.

The Open Systems Lab anticipates both future Open MPI maintenance releases and new research initiatives in the areas of fault tolerance, one-sided communications, additional high-performance transport technologies, and collective communication algorithms. OSL also plans to spin off two sub-projects from the Open MPI group: portable Linux processor affinity and an MPI testing tool. The LAM/MPI project is officially in maintenance mode, but has at least one more minor release pending.

OSCAR 5.0 is currently in beta testing, and will continue these efforts. The LAM and Open MPI projects have directly influenced the OSCAR project. Now that OSCAR has a stable infrastructure for multi-platform capabilities, its core is being broken apart into small plug-ins that can be composed together to support a wide variety of different environments, computing platforms, and targeted clusters. This composition capability will serve as a unifying effort, enabling easier development and maintenance between the OSCAR core and its spin-off projects.

OSL plans to continue work in synthetic programming to include important emerging hardware platforms and will also apply this approach to applications in bioinformatics and network analysis. They plan to continue large graph processing and visualization work with a focus on studying the understanding scalability of current approaches as few tools exist for processing and visualizing large graphs. To address the visualization problem, OSL researchers will study the problem of interactive graph visualization on large format display walls.

The OSL team also anticipates having a working version of their automatic device configuration on Pocket PC smartphones in the near future. Researchers will be investigating critical issues of user acceptance and the amount of control they have over the configuration of their devices.

In the area of health care, the Open Systems Lab plans to extend projects on technologies that empower people to manage and improve their own health. As part of this initiative, OSL is helping to organize a 1-day retreat of nurses and technologists from Pervasive Technology Labs to explore possible application areas.

During the next year the Open Systems Lab will increase the scope of its interactions with other research groups. The OSL team hopes to expand collaborations in application areas and to aggressively grow existing collaborations. As an example, the OSL will be collaborating with the IU BioComplexity Institute via shared students and joint proposals. Other potential collaborators include groups in Informatics, Computer Science, and at IUPUI. Collaborations outside of IU include Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, University of Tennessee, Oak Ridge National Laboratory, Rensselaer Polytechnic Institute, and SUNY Albany.

II.2. ADVANCED NETWORK MANAGEMENT LAB

Steven Wallace

Director

Lab Mission

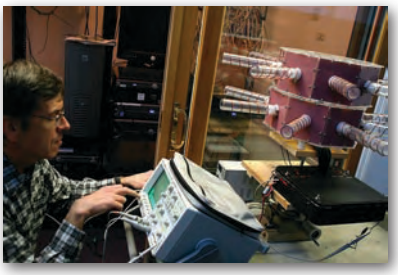
The mission of the Advanced Network Management Lab (ANML) is to perform research in the fields of network performance, management, and security; to use this research to develop new high-tech business opportunities in Indiana; and to contribute to IU's mission by collaborating with the School of Informatics, the Research and Education Networking Information Sharing and Analysis Center (REN-ISAC), the Center for Applied Cybersecurity Research (CACR), and the Global Research Network Operations Center (Global NOC). ANML provides support for facility research, including partnering on grant applications, network security education in support of CACR, network forensics assistance to the REN-ISAC, and the development of new tools for the Global NOC. ANML meets this mission with a combination of basic research, applied research, and development, education, and entrepreneurial development.

Summary of Key Lab Activities

The Advanced Network Management Lab continues to move forward in these key areas:

- **Advanced cybersecurity forensics, including active and passive intruder monitoring as well as application support for the Research and Education Information Sharing and Analysis Center (REN-ISAC).**
    - o ANML continued development of its Sebek forensic system, including the development of a new "filtered" version that significantly reduces the chances that a Sebek-equipped system will be detected by intruders.
    - o A paper was given on the system at the IEEE Information Assurance Workshop at the United States Military Academy in West Point, where the paper was one of seven selected as best paper. Another paper on economic deterrence mechanisms and the theory of system anonymization against attack was presented at the Workshop of the Economics of System Security in Cambridge, UK.

- **Wirelessand autonomous systems application services, including radiolocation and performance enhancements.**



The Porcupine wireless access point security tool is an ongoing project in the ANML used to locate and characterize wireless device activity within a wireless network — and to monitor for malicious activity in particular. Photo shows Porcupine project researcher Danko Antolovic with the device.

- o ANML worked on the design and construction of a prototype radiolocator for the "porcupine" wireless network locating system.
- o ANML researchers completed the design of a road-finding vision system for the Indy Robotics contestant, implemented in code, running at 3.5 GHz, processing 5 frames /sec, for the Defense Advanced Research Projects Agency (DARPA) "Grand Challenge"event. The system was tested on desert roads in California, during the Grand Challenge qualifiers.
- o Work done for DARPA resulted in the paper, "Vanishing Point: A Visual Road-Detection Program for a DARPA Grand Challenge Vehicle," Indiana University Computer Science Technical Report TR622, Dec. 2005.
- o A patent application was filed by the ANML for "Wireless Network Radiolocation Apparatuses, Systems, and Methods." Indiana University filed the application with the United States Patent and Trademark Office on April 5, 2006.
- o Another important publication was released entitled "Single-Packet Radiolocation of 802.11 Wireless Sources, Using an Array of Stationary Antennas and High-Speed RF Multiplexing," which appeared in the proceedings of Wireless Internet Conference (WICON), Boston, MA, 2006.

- **Education and community outreach, including infrastructure assistance.**
    - o Advanced Network Management Lab researchers presented "Wargames: An Exercise in Ethical Cracking," at the EDUCAUSE Security Professionals Conference, held in Denver, Colorado.
    - o The lab developed a Web-based RON map and participated in a demonstration of the Indy Robotics Vehicle for Indiana school children at the Intel International Science Fair, held in Indianapolis. The lab estimates that over 2,000 children viewed the display during the two-day display and over 700 students received photos of themselves with the vehicles. (See photos in Community Outreach section.)
    - o ANML Research Associate Danko Antolovic was nominated adjunct faculty in the Computer Science Department at Indiana University, where he is currently guiding two students through an independent study project.
    - o Resesarch Associate Mark Meiss and partners from the School of Informatics released the CenSEARCHip censorship exploration tool, which was featured in the Slashdot online newsletter. The tool received over 100 comments from interested parties on Slashdot and has been downloaded more than 45,000 times since its March, 2006, release.

Research and development activity

The Advanced Network Management Lab has and continues to maintain a formal relationship with the Honeynet Project and associated entities, including the Federal government. Major new activities in this space include a newly structured arrangement whereby ANML and Indiana University have taken the lead in the development of the Sebek cyber forensic tool. Specifically, ANML is moving forward to enhance the tool to enable both ubiquitous deployment, particularly on high-interaction key systems such as enterprise accounting systems, and the ability to cross-associate systems under attack. In this way, ANML researchers will be able to correlate system attacks that cross both enterprise and international boundaries without the need for cooperation at the international level. Nearly ten thousand lines of code have gone into this effort this year.

Investigation continues into techniques for identifying anomalous network traffic by analyzing behavioral patterns in network flow data. This is done by using Netflow records generated by the core routers in the Internet2 (Abilene) network to form a large graph structure whose statistical distributions and properties reflect different patterns of network use. Much of the current effort is directed toward improving the existing analysis code to work more efficiently on large datasets. The analysis software is also being made less specific to network flow data as a preliminary step to its integration in general purpose graph analysis software being developed by the Information Visualization Laboratory at Indiana University. Research is also being done on the effects of sampling bias (at both the router and analysis levels) on the statistical properties of the behavioral networks derived from Netflow data; the results are expected to have a direct impact on network flow analysis tools in general.

Research into security vulnerabilities in the Web has led to the discovery of a new form of "pharming" attack that can be used by an attacker in a local network to direct other users to an arbitrary Web site. The form of the attack is such that the attack is nearly undetectable; furthermore, it affects all current-generation browser and has no immediate workaround. Its potential impact is amplified by aspects of the authentication mechanism used by many Web-based services (especially online banking services) that make it possible for an attacker to replace legitimate login screens with no visual indication of tampering. A paper describing this vulnerability and suggesting various methods of ameliorating its effects has been written and is currently under revision for submission to an appropriate conference.

ANML has entered into a number of infrastructure partnerships over the last year, including a distributed attack detection and monitoring system with Columbia University and the deployment of a "PlanetLab" infrastructure for distributed experimentation in conjunction with the School of Informatics.

Intellectual accomplishments and external funding activity

- ANML Director, Steven Wallace was named Senior Advisor for Internet 2 on deployment of next generation research and education network backbone.

- Two (2) new peer-reviewed publications appeared in print during the reporting period.

- The ANML gave a total of four (4) presentations at academic meetings and conferences during the reporting period.

- The lab secured a grant award during the reporting period totaling $130,393.

- Four (4) additional grant proposals totaling $1,081,152 were submitted and are under continuing review.

Educating the residents of Indiana and beyond

- ANML participated in the Intel International Science and Engineering Fair, the world's largest pre-college celebration of science held in May. At the fair ANML presented "Don't Become a Casualty in the Information Revolution: Blogging and Life on the Web." The message of the presentation which was targeted at young people, was that the Internet has a long memory and that things that might not sound like a bad idea at the time can come back to haunt them. Examples were given, such as putting up pictures of oneself partying during college, pictures that one might not want a potential employer to run across several years later. Researchers Edward Balas and Mark Meiss were interviewed during the event for a story on the topic that ran on Indiana NPR radio stations.

- ANML also has several "roadshows" that it performs at various venues across the country. An example of one such program is the recent presentation on "Wargaming." to the EDUCAUSE conference. In this presentation, ANML staff members conducted a "live" exercise, targeted at educating CIOs and other high-level administrators that allowed them "hands on" access to the same type of tools used by system intruders. During the half-day workshop participants go through all of the steps typically used by system intruders. This helps participants to gain insight into the mindset of those who compromise systems, and teaches effective methods to combat them.

Accelerating economic growth

To date, ANML has launched one spin off company, SGC Technologies, LLC. SGC is currently in a growth phase, having hired the first two employees beyond its founders and the company is beginning development of its second generation FileShare technology. SGC Technologies, LLC has sold systems to Louisiana State University and has additional sales pending.

Bringing Distinction to Indiana University and the State of Indiana

The Advanced Network Management Lab continues to maintain a highly visible position in the research and engineering communities, particularly in the area of high-speed, long-distance computer networking and computer cybersecurity forensics. ANML Director Steven Wallace has recently been asked to assist in a key role with the University Consortium for Advanced Internet Development (UCAID) in its transitional and growth challenges in regard to its advanced Internet2 network.

Several collaborations with respected outside organizations maintained by the ANML are growing, particularly the ANML/Honeynet alliance. Lab alliances bring ANML researchers into regular contact with entities at the state and federal level. Finally, through our educational outreach programs and workshops, we maintain visibility for the lab, and for Indiana University. ANML personnel perform approximately three to five external presentations per quarter to various groups, the vast majority of them located outside the state of Indiana.

Lab Outlook, July–December 2006

Advanced Network Management Lab's outlook for this coming quarter is extremely positive in that the lab will continue to concentrate on the key areas described above. In addition, ANML plans to spend particular energy on outreach and collaborative efforts with other units within the university, particularly the Center for Cybersecurity Research (CACR) and the School of Informatics.

As part of these efforts, ANML will be soliciting additional federal grant funding. Specifically, ANML will focus on funding for collaborative efforts such as the recently funded effort between ANML and the University of Michigan.

The lab anticipates that their main focus in the coming period will be cutting-edge research and development in the cyber forensics fields and radiolocation services. In addition, ANML hopes to expand their educational outreach mission with a seminar series beginning in the spring of 2007.

II.3. COMMUNITY GRIDS LAB

Geoffrey Fox

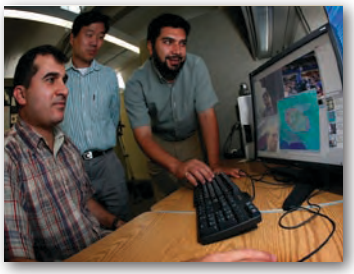
Director

Lab Mission

The mission of the Community Grids Lab (CGL) is to create technology that will enable grid computing to help solve important scientific problems. In creating new global communities, grid computing will open the way to new possibilities for e-business and e-science. CGL focuses on creating new technology infrastructure and applications that will enable distributed business enterprises and cyberinfrastructure for distributed science and engineering. Computers and networks are getting faster and the distinction between computers and the network is blurring. This fact suggests a future in which individuals and corporations interact with grid-based applications without needing to explicitly manage the underlying technology details. CGL's focus on applications has spawned much cross-disciplinary collaboration in research and development of scientific and business applications. A current major emphasis is in earth science and particle physics, with other projects including education, biocomplexity, chemistry, apparel design, digital film production, and sports informatics.

Summary of Key Lab Activities

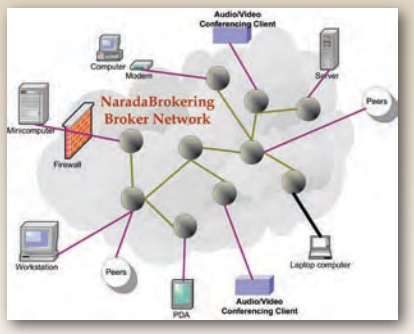
The Community Grids Lab continued its active research in the areas mentioned above, yielding 23 publications and 46 presentations in the six month period. A major accomplishment for the period was the receipt of three grants from Microsoft Corporation. The CGL spin-off company, Anabas, was awarded in partnership with the lab a phase II Small Business Innovation Research (SBIR) grant, a phase I Small Business Technology Transfer Innovation Research (STTR) grant, a 21st Century Research and Technology Fund matching grant, and a subcontract from Science Applications International Corporation (SAIC). This activity, along with four federal grants received in the previous reporting period, testifies to CGL's ongoing success in leveraging the Lilly Endowment-funded research to attract additional funding to the state of Indiana.



Researchers demonstrating Collaboration Grids technologies.

The work of CGL and Anabas exploits the world-wide communication fabric that allows one to electronically link computers, data repositories, sensors, and people across the globe. This capability underlies the World Wide Web that enables Amazon to sell books, electronic auctions like eBay, online information and search tools like Google, and Internet telephony such as that done by Skype. It also enables the exchange of files that is revolutionizing the music distribution industry. Grids use the same communications backbone and the same core software concepts to support more sophisticated managed electronic linkages such as those needed to support international science teams analyzing data from telescopes, accelerators, and seismic sensors.

CGL develops some core technologies, but also collaborates with other leading groups to build "managed electronic communities" for a variety of applications. These include groups devoted to earthquake science and the integration of chemistry and biology for drug discovery—while Anabas is addressing the real-time constraints of operational homeland security and military grids as well as the linkage of designers and manufacturers in the textile industry. New CGL projects awarded in this period address the role of publishers and journals in the digital age as well as the programming of the new multi-core chips that will revolutionize computer architecture. Specific CGL technologies include those supporting interactive maps, the transfer of information between resources, audio-video conferencing, and the use of Peer to Peer (P2P) and Web 2.0 approaches in scientific research. CGL continues its commitment to the broad participation of all Americans in cyberinfrastructure with collaborations with the major higher education organizations representing historically Black, Hispanic, and American Indian communities. CGL research broadly supports the inevitable globalization of industry and academia with a synergistic mix of technology, applications, and partners.

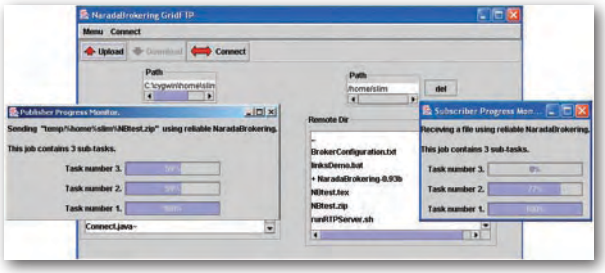


The NaradaBrokering network and access to services.

Research and Development Activity

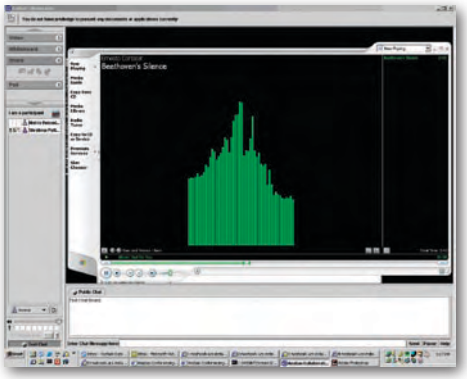
A description and update of major Community Grids Lab Projects appears below:

Grid Architecture. The Community Grids Lab continued core research in the grid and Web services architecture which acts as a backdrop to all their projects. CGL researchers continued a general analysis of services to identify areas where further work is needed by the global community. This activity identified data and metadata federation as a critical area where there are several approaches, but no consensus on the appropriate architecture. At an international conference in Paris this June, CGL presented on the first scalable approach to quality of service and the management of services.



The NaradaBrokering-enhanced GridFTP system.

NaradaBrokering Grid Messaging System. CGL has released three versions of the NaradaBrokering code base during this period and the current version of the software is 1.1.6. Project scientists have built prototypes of modules related to replication of stable storage, and to track the availability of entities in large-scale distributed systems in a scaleable fashion. The replication feature provides redundancy and fault-tolerance to several services such as reliable delivery, recording, and replay services. The team has also incorporated support for generic replay services within this time-period. Two major papers were published during the period: one on "Challenges of Large Applications in Distributed Environments (CLADE)" related to management of the substrate was presented at the Institute of Electrical and Electronics Engineers (IEEE) Workshop and the other, addressing security architecture in NaradaBrokering, appeared at the 7th IEEE/ACM International Conference on Grid Computing.



The Anabas conferencing system that leverages NaradaBrokering.

Open Middleware Infrastructure Institute Software. Community Grids Lab receives funding from the United Kingdom Open Middleware Infrastructure Institute (OMII) to develop core Web Service (Grid) support for reliable messaging (FIRMS) and notification (FINS). During the reporting period the lab has released 3 versions of the FINS software, the current version being FINS-1.0.10. It has also released two versions of FIRMS, with the current version being FIRMS-1.0.2. Both software projects have been successfully deployed within the latest version of the OMII Container. The projects received an extension from OMII in January and were scheduled end on July 15th.

Screenshot of Open Grid Computing Environments (OGCE) project.

Portals. The NSF has funded an Open Grid Computing Environments (OGCE) project, a collaborative effort between the Community Grids Lab and several other partners which continues to develop standard compliant portlets that work with several versions of the Globus Toolkit and Condor. The OGCE also develops numerous services to support portals, thus providing the tools needed to build an entire science gateway. With their collaborators, CGL's team has concentrated on both fundamental development work as well as deployment issues

During this period, the Community Grids Lab made a major new release of the OGCE portal software, providing all necessary portal software that can be downloaded and installed in a single installation. They continued collaboration with the Knowledge Acquisition and Projection Lab (KAPL) to develop and deploy the next generation of their Common Instrument Middleware Architecture (CIMA) crystallography portal. The updated CIMA portal is now available and has also been packaged and installed for CIMA collaborators in Australia. Efforts are continuing on the Virtual Lab (VLAB) portal, and the NSF-funded computational chemistry and material science grid. New portal efforts launched in this period include a portal to support the NIH-funded Chemical Informatics Cyberinfrastructure Center (CICC) portal and a next generation of the QuakeSim portal, to be made interoperable with the NASA REASoN portal.

SERVOGrid and Geographical Information Systems. The SERVOGrid project continues to develop and deploy an integrated "grid of grids" that uses workflow technology to integrate Geographical Information System-based data grid services, information services based on UDDI and WS-Context, and execution grid services for remote application management. All infrastructure code, including GIS Web services and workflow tools (HPSearch), are developed in-house by Community Grids Lab graduate students who are funded by the NASA Advanced Industrial Science and Technology (AIST) program. During the previous six months, we have worked to develop improved map interfaces with the Google Map API (supplementing our previous Web Map Service-based system), to add additional modeling applications, to provide enhanced performance of archival services by using data streaming technologies, and to provide sequential filtering on live Global Positioning System data feeds that can be used for real-time event detection using codes developed by collaborators at the Jet Propulsion Lab (JPL). This software is now being deployed to support the Scripps Orbit and Permanent Array Center (http://sopac.ucsd.edu/).

Community Grids Lab has also initiated a collaboration with the POLIS center at IUPUI to develop an integrated, high-performance map server of central Indiana. This map server bridges the difference between underling GIS vendor software (such as ESRI and Open Geospatial Consortium software) to provide a seamless, federated map server. By adopting tiling and caching techniques, the CGL researchers have greatly enhanced performance and interactivity of Web clients that use these map servers. This project's success was recently demonstrated to a meeting of university, state, and local government officials.

Collaboration Grids—Global MMCS (MultiMedia Collaboration System). The Global MMCS project is creating new technologies to allow videoconferencing in which a diversity of end-user devices are supported, and which provides support for participants who join a videoconference late or need to asynchronously observe a video conference after it has taken place. CGL researchers finished a GoogleDesktop plugin that allows individuals to connect to Global-MultiMedia Collaboration System (MMCS) servers through their Google desktop installations. This new plugin can display the snapshot of video streams in the connected Gobal MMCS meeting and enable users to launch the new SWT-based client. The team believes this is an interesting new interface that will encourage broader use of collaboration technologies. This technology and our analysis of the integration of community and collaboration tools was presented at the CTS06 Conference this May, where CGL shared an exhibit space with Anabas.

Chemical Informatics Grid (CICC). Community Grids Lab made significant progress in this project over the previous six-month period, building numerous new Web services and deploying them on CGL servers, and prototyping several chemical informatics scientific usage scenarios as workflows (service orchestrations). Example services include data services for accessing NIH databases, services for accessing cluster modeling codes for organizing chemical data sets, services for translating between common chemical formats, and services for manipulating tabular data, which we based on the Virtual Observatory community's VOTables XML format. During the next six months, the team plans to deploy services for chemical text analysis, evaluate the use of Condor as a super-scheduler for managing Professor Mookie Baik's VARUNA codes on the NSF TeraGrid, and build the initial CICC Web portal.

Minority-Serving Institutions Cyberinfrastructure Institute (MSI-CI2). The MSI-CI2 initiative will help to ensure that a diverse group of scientists, engineers, and educators from historically underrepresented minority institutions are actively engaged in the development of new cyberinfrastructure (CI) tools, strategies, and processes. CGL held three separate workshops in collaboration with the national cyberinfrastructure centers National Center for Supercomputing Applications (NCSA) and San Diego Supercomputer Center (SDSC) for training and planning with key MSI participants. The CGL research team was also invited to join a TeraGrid planning group to facilitate better understanding of how to bring in all of America, and especially the MSIs, as equal partners onto the TeraGrid.

Intellectual Accomplishments and External Funding Activity

- Internationally recognized scholar Dr. Marlon Pierce was named Assistant Director of the CGL during the reporting period.

- The CGL had one (1) new technology disclosure during the reporting period and distributed six (6) new packages of open-source software, including: OGCE Portal 2.6, HPSearch 1.0.1.3, WS-Context 0.9v4, NaradaBrokering 1.1.6, FIRMS 1.0.2, FINS 1.0.11.

- Twenty-three new peer-reviewed publications authored by CGL appeared in print during the reporting period and the lab has produced a total of 267 publications since inception.

- The CGL gave a total of 46 presentations at academic meetings and conferences during the reporting period.

- Community Grids Lab Director Geoffrey Fox was named Vice President of the eScience Division for the Open Grid Forum.

- Five (5) grant awards were made to the lab, totaling $772,033, during the reporting period.

- An additional five (5) grant proposals, totaling $4,239,073, were submitted and are under continuing review.

Educating the Residents of Indiana and Beyond

The previously described Minority-Serving Institutions Cyberinfrastructure Institute has focused on appropriate new curricula for teaching cyberinfrastructure and this project work has implications for schools in the state and across the country. The CICC project has a significant component of developing the chemical informatics education program at Indiana University and Eli Lilly scientists have already shown great interest in the project. As part of CGL's interest in globalization, the lab has significant ongoing and planned activities in Latin America, China, and Africa.

Accelerating Economic Growth

In collaboration with the Community Grids Lab, Anabas was very successful on its phase I SBIR award. This initial success led to the award of a $750,000 phase II collaboration with CGL and Ball Aerospace which started in June 2006. Anabas also obtained $100,000 in a matching grant from the Indiana 21st Century Research and Technolgy fund and started a partnership funded by the Air Force, with the major corporation SAIC. Anabas is continuing to develop its e-Textile application and evaluating use of GlobalMMCS technologies. CGL bid a successful Department of Energy (DOE) STTR contract with Deep Web Technologies of Santa Fe, New Mexico, to apply the CGL Grid architecture to particle physics data analysis. This project is being done in collaboration with leading Caltech physicists.

Bringing Distinction to Indiana University and the State of Indiana

Community Grids Lab has successfully obtained 10 new grants in the past year, and their work has attracted the attention of large academic and corporate supporters such as Microsoft. The lab has also received numerous invitations from international institutions and organizations to assume guest leadership and academic positions, illustrating how their work has helped Indiana University to be viewed as a leader in CGL's research areas. Lab researchers obtained courtesy positions at the University of Southampton UK (professor), the Alliance for Equity in Higher Education and a major institution that serves Hispanics, MSI University of Houston Downtown (visiting scholar). CGL researchers are leading an effort to link the cyberinfrastructure of the United States, Australia, China, and Japan to support earthquake science. And lab Director Geoffrey Fox has been nominated to be the new vice president of e-science of the Open Grid Forum, which was recently formed from the merger of the Global Grid Forum and the Enterprise Grid Alliance.

Lab Outlook, July–December 2006

The Community Grids Lab anticipates a very productive 2006, with long-term activities reaching new levels, and the increasing momentum of roughly 10 new projects started in the past nine months. The lab plans to add new full-time research staff and several graduate student assistants, and they anticipate approximately six of their current Ph.D. students will graduate during the period. Major effort will be put into the new Microsoft-funded projects with Rice and Tennessee Universities. CGL will hold a kickoff workshop for the project in the upcoming period. The new SBIR and STTR projects will use many existing CGL technologies and expertise, but will deliver them to military and particle physics applications. Lab researchers started a modest Web 2.0 activity in the current reporting period that, with the assistance of Microsoft funding, will expand to include research of a novel new scientific environment covering complete activity from initial data through published results. (To see the outlook on specific CGL projects, please visit www.pervasive.iu.edu.)

II.4. VISUALIZATION AND INTERACTIVE SPACES LAB

M. Pauline Baker

Director

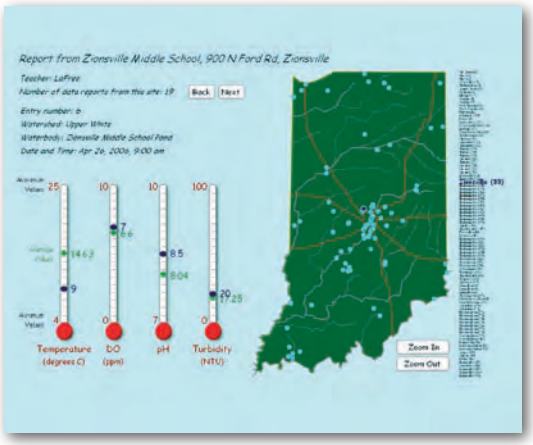
Lab Mission

The mission of the Visualization and Interactive Spaces Lab (VIS Lab) is to use advanced computer-generated graphics and novel sensor-based user interfaces to create innovative environments for data exploration, learning, and visualization of science data. The goal is to create new capabilities for access to information, and to embed these capabilities into environments for exploration and learning. The lab's research agenda includes user interfaces, display innovations, graphics software, and providing visualization functionality over the Web. The lab is especially interested in taking a collaborative approach, where technology solutions can contribute to applications that affect people's lives now.

Summary of Key Lab Activities

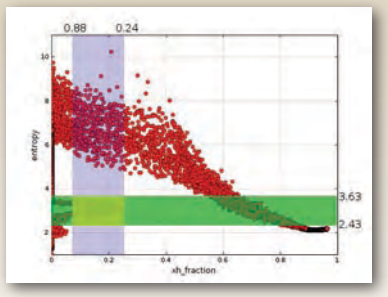
During this reporting period, the VIS Lab and collaborators in the Center for Earth and Environmental Science (IUPUI School of Science) were awarded initial funding for the program Discovering the Science of the Environment (DSE). This first gift comes from Veolia Water Indianapolis, water supplier for central Indiana. Discovering the Science of the Environment is aimed at providing inquiry-based opportunities for learning about environmental science for children and their families, as well as professional development for educators. The program consists of a number of components, including information delivery over the Web, field trip experiences focused on data collection and analysis, a mobile environmental science trailer, an equipment loan program, and a professional development program. In all cases, the goal is to provide authentic inquiry-based opportunities for learning about science. Recognizing that today's learners are growing up in a completely digital and media-rich world, the program will make heavy use of technology to entice, engage, and empower.

The team's plans and ideas for Discovering the Science of the Environment are ambitious, and the program is feasible and sustainable only because the VIS Lab can rely on a number of existing programs and relationships. As just one example, the IUPUI Community Learning Network already runs the Teachers Resource Network equipment loan program, with FedEx providing free delivery and pickup of kits through the nine-county region. Additional conversations are underway with additional funding sources, including Nina Mason Pulliam Charitable Trust. The VIS Lab anticipates having new positive outcomes arise from some of these conversations by the end of July.



The Watching Your Watershed exhibit at the Indiana State Museum provides visualization tools for local Indiana watersheds.

Discovering the Science of the Environment extends and formalizes the Visualization and Interactive Spaces Lab's earlier work towards interactive experiences for learning about the environment. VIS Lab's previously reported work includes the Riverside PercepTable application for exploring data from the Lilly ARBOR project, the LillyPad PDA software that introduced the use of PDA-based digital resources as part of the ARBOR data collection process, and the Watching Your Watershed exhibit in place at the Indiana State Museum. The program also extends the lab's relationship with the Center for Earth and Environmental Science (CEES)—a connection that was strengthened early on by awards from the PTL Faculty Fellows program.

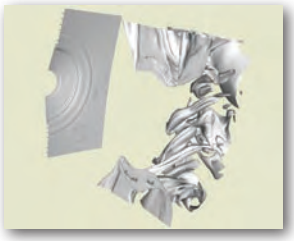


From the TeraScale Supernova Project: Supernova scientists are interested in the relationship of entropy and the fraction of heavy nuclei.

The VIS Lab also concentrated considerable effort in furthering the design and prototyping of VisPort. VisPort is a system to support access to high-performance visualization capability via the Web. This system is partially motivated by the lab's long-running collaboration with the TeraScale Supernova Initiative, which produces simulation output that is much too large to analyze and visualize on desktop computers. The intent of VisPort is to provide Web-based access to visualization software running on a remote, larger machine. Additionally, VisPort is an experiment in capturing the "informatics layer" of visualization, including information about who produced the visualization, what datasets were used, the input parameters and other visual mapping parameters, etc. This sort of information is extremely useful for a variety of purposes but is generally not captured by today's visualization tools.

In terms of personnel, the lab said a fond goodbye to Rob Stein, who left to take a job with the Indianapolis Museum of Art. Mr. Stein's new position came about as a natural outgrowth of the VIS Lab's successful collaboration with the museum. While the lab does miss Mr. Stein, they view the movement of personnel as one of the most profound forms of technology transfer. Not only did the PTL Program import his talent to Indiana, but the VIS Lab strategy of partnering with community groups ultimately led to the long-term embedding of his talents in one of the region's most important cultural institutions.

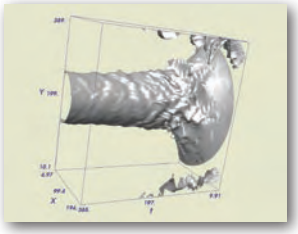
From the TeraScale Supernova Project:



The evolution of high-velocity regions of electron fraction over time.

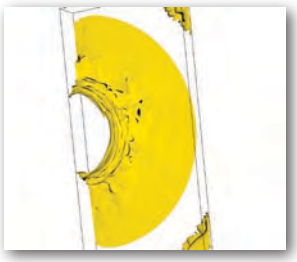
Research and Development Activity

A description and update of major Visualization and Interactive Spaces projects appears below:



This shows the boundary between low and high regions of electron fraction over time.

Discovering the Science of the Environment. In addition to formally launching the program, VIS Lab staff worked on ARBOR Quest and the Statewide Water Quality Investigation. In the Statewide Water Quality Investigation effort, off-the-shelf water sampling and analysis kits were made available free to any interested participants. A Web site allowed participants, many of whom were classroom teachers, to upload results of their analysis. VIS Lab staff took that data and produced an interactive visualization tool to show the statewide results. This was something of a trial run, designed to see what role this kind of exercise might play in the DSE program. ARBOR Quest is an interactive data exploration tool that extends our earlier work on Riverside, visualizing the data from the ARBOR ecosystem restoration project. Within the lab, ARBOR Quest is serving as a driver application for one research effort (aimed at capturing and analyzing interaction patterns) and two software development efforts (to model and graphically display a 3D ecosystem, and to extend the PercepTable to accommodate Flash-based applications).



This (also) shows the boundary between low and high regions of electron fraction over time.

Scientific Visualization Collaborations. The VIS Lab also continued its work with the TeraScale Supernova Initiative (TSI, DOE-funded) and Inverse Ocean Modeling (IOM, NSF-funded) collaborations. The TSI collaboration comes to a close this summer. Part of our activity during this reporting period was to participate with the larger group and submit the proposal for continuing this work under Phase 2 of the DOE SciDAC program. We also continued to craft visualizations for use by the scientists. Similarly, under the IOM collaboration, we crafted new visualization techniques for covariance visualization.

VisPort. For both TSI and IOM, the VIS Lab is interested in embedding their visualization techniques in a framework that would allow users to create visualization over the Web. This approach is consistent with the current work towards science gateways—easy-to-use, Web-based entry points into community-based applications running on remote computing resources. VisPort work is an experiment in specifying and architecting such a gateway for visualization.

Intellectual Accomplishments and External Funding Activity

- VIS Lab Director M. Pauline Baker has been named co-director of the Discovering the Science of the Environment program.

- The lab has created three (3) hardware applications, installed and in use in educational settings in the central Indiana region. For more information on these applications, please visit www.pervasive.iu.edu.

- The lab gave seven (7) presentations at academic meetings and conferences during the reporting period.

- The VIS Lab was awarded a grant totaling $50,000 during the reporting period, all of which flows directly into the lab.

- Two (2) grant proposals, totaling $1,459,538, were submitted and are under continuing review.

Educating the Residents of Indiana and Beyond

The Intel International Science and Engineering Fair was hosted at the Indianapolis Convention Center in early May. VIS Lab staff served as judges in the Computer Science category. In addition, their visualization software developed for the Statewide Water Quality Investigation was shown during the fair in the interactive exhibits hall.

The lab participated in technology presentations in the ICTC involving 136 visitors. Of particular note, lab staff recently spent half a day with 24 students from the Louis Stokes Alliance for Minority Participation (an NSF-funded program) and the Ron McNair Scholars program, introducing these students to graphics technology and visualization applications. One of the students from the NSF LSAMP program is working in the VIS Lab for the summer, with Dr. Baker as her mentor.

Visitors to the Indiana Humanities Council Leadership Summit hosted by the Visualization and Interactive Spaces Lab view a demo of the PerceptTable.

Accelerating Economic Growth

With an initial award from the IURTC IPCRES investment committee of $50,000, work is underway at the Visualization and Interactive Spaces Lab's spin-off company, EnVizable, LLC, to develop a more complete business plan.

Bringing Distinction to Indiana University and the State of Indiana

The Visualization and Interactive Spaces Lab was honored to recently participate in the Indiana Humanities Council Leadership Summit, an annual event that gathers a statewide audience of community leaders. Lab Director Baker participated in the kick-off ceremonies at the Hilbert Theater by introducing the stereoscopic movie *Painting with Electrons*. This film, produced by School of Informatics faculty Albert William, with technical direction by the VIS Lab, has been widely shown to many audiences—the positive reaction of the Leadership Summit attendees came as no surprise. Baker was also the featured speaker at a Leadership Summit soiree, speaking on the "Power of New Media: A Second Gutenberg Revolution." The soiree, including dinner, was held in the VIS Lab Gallery space, which gave VIS lab staff the opportunity to show their recent innovations, as well as the other advanced visualization applications and facilities housed in the new ICTC building.

Lab Outlook, July–December 2006

During the next six months, efforts of the Visualization and Interactive Spaces Lab will focus on advancing the Discovering the Science of the Environment program. In particular, the lab will be working with colleagues from the School of Education and experienced classroom teachers to identify curriculum modules where our efforts can make an impact and to design technology-based experiences that can best support those parts of the curriculum. Already underway is some design and implementation of a PDA-based application for water quality monitoring and analysis, based on the VIS Lab's successful experience with the LillyPAD application. VIS Lab researchers will also be reviewing and updating plans for the mobile environmental science discovery vehicle.

In the fall, the VIS Lab will put into place a student internship program. A cohort group of 4–6 students will be brought into the lab for a semester or a year to work on a particular project. Students will be expected to commit to a substantial number of hours of paid work per week. The opportunity to apply classroom skills to a year-long project will deepen the students' skill sets and contribute to building their portfolios of completed work. Students in informatics and computer science are obvious candidates, but the lab may also recruit students in computer technology, engineering, education, and the new museum studies program.

Finally, The VIS Lab will work closely with the Scientific Data Analysis Lab (SDA Lab) in furthering the design and implementation of VisPort.

II.5. SCIENTIFIC DATA ANALYSIS LAB

Randy Heiland

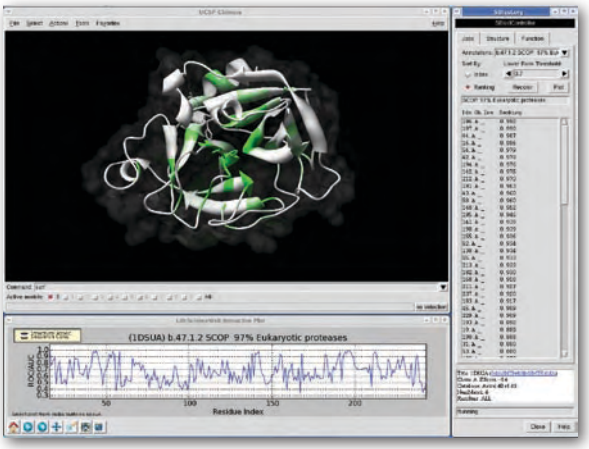
Associate Director

Lab Mission

The mission of the Scientific Data Analysis Lab (SDA Lab) is to develop and deploy software tools and applications that contribute to improved science understanding and education. The Lab actively seeks academic researchers and educators who have challenging problems in scientific data management, analysis, and visualization. While the lab is interested in tackling problems in many scientific domains, the staff is currently focused on challenges in the life sciences—an area of rapid growth in the state of Indiana. The lab is also committed to science and mathematics education in its K–12 outreach efforts.

Summary of Key Lab Activities

The SDA Lab continued its core mission of building scientific collaborations and applying state-of-the-art information technology towards advancing science research. Within the context of its longstanding collaboration with the Center for Computational Biology and Bioinformatics at IUPUI, the SDA Lab is hosting three new online services and has also published another paper on the research. With a research group in the Department of Chemistry at Purdue, the lab continued to develop and promote a software tool for analyzing nonlinear optical properties of molecules. SDA Lab researchers renewed a collaboration with the Biocomplexity Institute at Indiana University, with the goal of developing an open-source toolkit for modeling cellular tissue. During this period, the lab has submitted two proposals to fund these activities. The team also worked closely with the VIS Lab on the design and prototyping of VisPort, a system for remote access to visualization functionality. Finally, the SDA Lab contributed in several ways to the Intel International Science and Engineering Fair, held in Indianapolis in May.

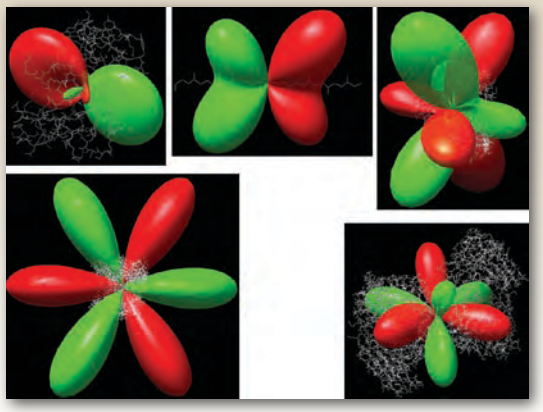


Demonstrating a Life Science Web service in a Chimera client application.

Research and Development Activity

In the SDA Lab's ongoing collaboration with the Mooney Lab in the Center for Computational Biology and Bioinformatics at IUPUI, SDA researchers continued to promote and develop their life science-based services (www.lifescienceweb.org). The group delivered three poster sessions on this work—one at the Pacific Symposium on Biocomputing, in Maui; another at the 2006 Solutions Conference, at IUPUI; and another at the Third Annual Bioinformatics Conference, at IUPUI. They also published a paper on one of their more recent online services, to submit and characterize proteins based on their structure and sequence, in *BioMed Central Structural* Biolog, a peer-reviewed open-access journal.

The lab has continued development of the NLOPredict application as part of an ongoing collaboration with the Simpson Group in the Department of Chemistry at Purdue University. NLOPredict rapidly predicts and visualizes information about the orientation of molecules at biological interfaces. In March, the SDA Lab, the Simpson Group, and two other university groups submitted an NSF proposal to fund this work. In May, the team participated in a regional workshop at Purdue where they demonstrated and taught other researchers how to use NLOPredict.



Visual representations from the NLOPredict application.

The SDA renewed their past collaboration with the Biocomplexity Institute (BI) at Indiana University and resubmitted an NIH proposal to fund the development of a tissue simulation software package. This project would provide an open-source tool for cell-based modeling of tissues and organs and is joint work with the BI, Notre Dame, and the Keck Graduate Institute of Claremont, CA.

SDA Lab researchers also worked closely with the VIS Lab in the design and development of VisPort. VisPort is intended to be a Web-based portal, or science gateway, for visualization on high-performance resources. The SDA Lab's expertise in using Web services for visualization, developed earlier through their work with the Mooney Lab, provides some key underpinnings for the VisPort architecture.

The Lab was fortunate to hire a unique graduate research assistant during the reporting period. Gary Cravens is currently a Ph.D. student in informatics at IUPUI. He holds an M.D. from the IU School of Medicine and has worked at the Mayo Clinic, the University of Pittsburgh Medical Center, and in medical informatics private industry in Minneapolis. In addition, he has M.S. degrees in physiology, physics, and computer science. Gary is currently working with Michael Miller, one of the SDA Lab's collaborators in the Imaging Science section of the Department of Radiology at the IU School of Medicine. Gary's initial project is to quantify blood flow to the heart using PET imaging, using the Ossabaw pig as the model study. The lab has introduced Gary and Michael to the Insight Toolkit (ITK), a well-respected, open-source software package that serves as a good alternative to the commercial software package they had been using for image analysis.

Intellectual Accomplishments and External Funding Activity

- Associate Director Randy Heiland was named a member of the Curriculum Committee for the 2006 Supercomputing Conference Education Program.

- The SDA Lab delivered one new online service during the reporting period.

- Two (2) new peer-reviewed publications appeared in print during the reporting period.

- The lab gave a total of three (3) presentations at academic meetings and conferences during the reporting period.

- Two (2) grant proposals, totaling $708,636, were submitted and are under continuing review.

Educating the Residents of Indiana and Beyond

- Staff from the SDA Lab served as Computer Science Grand Awards Judges in the annual Intel International Science and Engineering Fair, an amazing event that brought together nearly 1,500 high school students from 47 countries to Indianapolis in May. In addition to serving as judges, the lab also hosted an Interactive Discovery Exhibit, describing and demonstrating their software applications. During this day-and-a-half event, SDA staff members were able to share their enthusiasm for science and mathematics with many students, teachers, and administrators.

- In February, Heiland gave a talk at the Hoosier Association of Science Teachers, Inc., conference at the Indianapolis Convention Center about using open-source software for enhancing K–8 science and mathematics learning. In March, Heiland and Katie Browning, Director of the Girl Scout Math & Science Center at the Hoosier Capital Council, presented a related poster at the annual Teaching and Learning with Technology Conference at Purdue.

SDA Lab conducts a follow-up summer workshop for the Supercomputing '05 Education Program to math and science teachers.

The lab participated in several technology presentations in the ICTC that were seen by several hundred visitors. Of particular note, SDA Lab staff recently spent half a day with 24 students from the Louis Stokes Alliance for Minority Participation (an NSF-funded program) and the Ronald E. McNair Scholars Program, introducing these students to graphics technology and visualization applications.

Bringing Distinction to Indiana University and the State of Indiana

Associate Director Randy Heiland will represent the SDA Lab and Indiana University as a member of the Curriculum Committee for the 2006 Supercomputing Conference Education Program. The annual supercomputing conference is a paramount event in the supercomputing arena, drawing exhibitors and attendees from around the world.

Lab Outlook, July–December 2006

During the next six months, the Scientific Data Analysis Lab will focus on further design and development of the VisPort architecture. Special attention will be paid to ensuring that VisPort can carve out a unique niche, by capturing the informatics layer of visualization, integrating with workflow systems, accommodating community-specific user interfaces, and leveraging IU's impressive computing infrastructure. As the lab moves forward, the team will identify research collaborations with which they can partner as application drivers for VisPort. Their goal is to demonstrate and market a working system at the annual Supercomputing conference in November.

II.6. KNOWLEDGE ACQUISITION AND PROJECTION LAB

Donald F. (Rick) McMullen
Director

Lab Mission

The mission of the Knowledge Acquisition and Projection Lab (KAP Lab) is to develop new insights about how knowledge is created, managed, and used within organizations, and then use this knowledge to develop advanced information technology systems that will create new possibilities for management, delivery, and use of institutional knowledge. Some application areas for the technology developed by the KAP Lab include:

- Managing the data and information produced by arrays of sensors, such as ocean buoys;
- Creating tools to enhance problem solving in distributed and virtual organizations;
- Knowledge management for innovation in virtual organizations; and
- Just-in-time information delivery systems for distributed organizations, such as delivery of information needed to repair the highly technical infrastructure and equipment on board Navy ships.

The Knowledge Acquisition and Projection Lab is currently unique among Pervasive Technology Labs in that it is almost entirely self-funded.

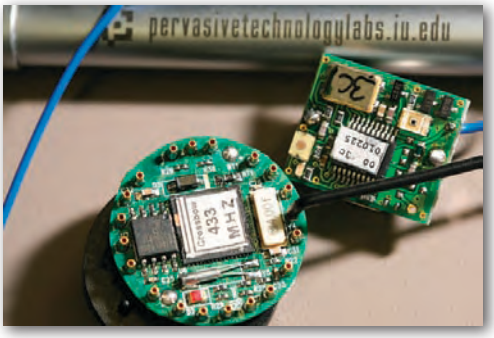
Summary of Key Lab Activities

Highlights of key lab activities are listed below:

- KAP Lab co-organized a workshop entitled "Scientific Instruments and Sensors on the Grid," which was held at the joint 2nd International Conference on Intelligent Sensors, Sensor Networks, and Information Processing (ISSNIP 2005) and IEEE International Conference on eScience and Grid Computing (eScience 2005).

- Lab staff participated in demonstrations of sensor network technology developed for a National Ecological Observatory Network (NEON) and Long Term Ecological Research (LTER) Lake Metabolism network at the Coral Reef Environmental Observatory Network workshop held March 29–31 in Townsville, Australia. Software developed for this project includes a distributed, agent-based signal processing and condition monitoring system.

- Scientists from the KAP Lab conducted field research for an NSF-sponsored project to understand coordination in policy making and priority setting regarding basic research between the NSF and its cognate agency TUBITAK in Turkey. The primary aim of the project is to learn how funding agencies interact to support international scientific collaborations. It is expected that the scope of this project will expand to include additional countries in the Middle East and Asia-Pacific regions.



Minature wireless sensors for building a continuous real-time understanding of our world. The KAPlab, with the NSF Middleware Initiative, is developing innovative middleware to connect instruments and sensors such as these to the world of Grid computing and storage resources. Through this combination of real-time, real-world information and large scale computing and storage we can better model our environment, predict the effects of natural or man-made distasters, and plan to reduce their impact.

Crane and KAPLab groups working on software to improve the Navy's maintenance process. (Photo by Tyagan Miller)

Research and Development Activity

During the reporting period, the KAP Lab hired a research scientist, formerly employed by Samsung and Microsoft, to develop a research program in ubiquitous computing services and advanced training technologies. This research program will look at how existing and near-future information and computing technology infrastructures can be used to deliver advanced personal services to mobile devices and fixed stations in homes and workplaces, and what these services can offer to improve the quality of life for people of all ages.

The lab continued work on an NSF Middleware grant project to develop Common Instrument Middleware Architecture (CIMA) software and applications. A network of X-ray labs using this software has added two new members during the reporting period. A related collaboration with two Australian universities and a major Australian Research Council project on large-scale data management is working to integrate the CIMA software base with Storage Resource Broker to create a national lifecycle approach to, and facilities for, e-research data management.

KAP Lab researchers continued to collaborate with the Open Grid Computing Environments (OGCE) group to develop novel multiuser interfaces to remote instruments and sensors.

New projects started during the reporting period include:

- research to develop new distance learning support systems and techniques
- using training scenarios to derive situation awareness (SA) requirements for complex systems and to remediate SA-induced operator errors in system design
- leveraging anomalous microwave propagation effects to enhance network range in marine sensor networks

In addition, the lab participated in the development of an extended collaboration, the Diffraction Grid, consisting initially of IU, the University of Wisconsin, and the Advanced Photon Source (APS) at Argonne National Labs. The purpose of this collaboration is to develop a national shared infrastructure for teaching and applying X-ray and neutron diffraction methods in chemistry, biology, and materials science. Additional facility and educational participants as well as additional funding will be sought in coming months to expand the collaboration.

Intellectual Accomplishments and External Funding Activity

- The KAP Lab had one (1) new technology disclosure during the reporting period and released one (1) new package of open-source softare, CIMA Crystallography Lab Software.

- The lab had one (1) new peer-reviewed publication appear in print during the reporting period.

- The lab gave a total of two (2) presentations at academic meetings and conferences during the reporting period.

- Three (3) grant proposals, totaling $2,218,705, were submitted and are under continuing review.

Educating the Residents of Indiana and Beyond

The Diffraction Grid project was started to promote the use of X-ray and neutron diffraction methods in chemistry, biology, and materials science. These techniques are a critical approach to molecular structure but are not currently well represented in university and professional training curricula. The initial partners (IU, the University of Wisconsin, and the APS) represent higher education in Indiana and the Midwest, coupled with a potential high-tech employer, Argonne National Lab.

Accelerating Economic Growth

KAP Lab spin-off company KBE Systems, LLC, is developing software systems for knowledge-based engineering (KBE) in mechanical structural engineering. These systems are CAD/CAE/CAM products that include information about both materials properties and manufacturing processes. Work KBE is doing in partnership with another Indiana business has received attention and support from outside entities and funding agencies.

Bringing Distinction to Indiana University and the State of Indiana

The KAP Lab's previously described work with high-profile collaborators in Australia and Turkey on projects to study ecosystems and science research funding has helped to forge and grow important international partnerships for the university. The collaborations demonstrate to the international community Indiana University's expertise in and dedication to the development of technologies that help researchers study and understand important social, educational, and environmental challenges facing our communities and the world.

Lab Outlook, July–December 2006

The lab will be submitting several grant proposals in the summer and fall of 2006 related to its interests in sensor networks and organizational learning. The lab will also be exploring partnerships with companies to commercialize technologies developed within the lab related to automated diagnostic systems and distance support.

Marine Sensor Networks: Researchers install a new sensor on a buoy at the Trout Lake Station in Wisconsin.

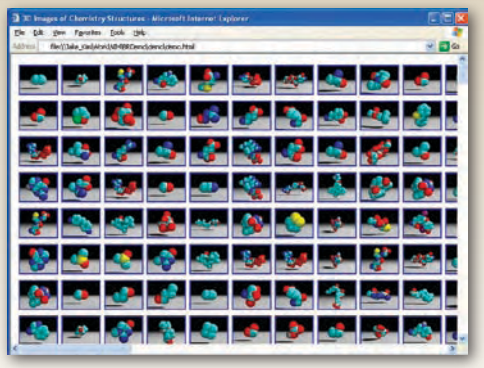
III. COLLABORATIVE AND LEVERAGED ACTIVITIES

One year ago, the Office of the Vice President for Information Technology asserted in the 72-month Pervasive Technologies Report that the changes in leadership of Pervasive Technology Labs would lead to increased collaboration between Pervasive Technology Labs and University Information Technology Services. Today, we can report significant success in enhanced collaboration between Pervasive Technology Labs and UITS. In addition, it is possible now to more fully indicate the impact of Pervasive Technology Labs on the research productivity, and grant success, of the university as a whole. Indiana University has very successfully leveraged Pervasive Technology Labs staff and expertise to obtain funding and resources that might not have otherwise been possible. While the principal investigators of these efforts may not reside within the labs, they all involve personnel affiliated in significant ways. Recent key activity in major collaborative and leveraged projects is described in the following pages.

Grant- and Contract-related Activity

- **TeraGrid.** IU's involvement in the TeraGrid continues to be the prime example of collaboration between Pervasive Technology Labs and other components of Indiana University. The TeraGrid is the National Science Foundation's flagship effort to create a national cyberinfrastructure to accelerate innovation and enhance productivity of U.S. researchers. "Cyberinfrastructure" refers to high-performance computers, massive data storage systems and data resources, advanced instruments, visualization systems, and people all interconnected by high speed networks. This concept is deceptively easy to grasp by analogy with the power infrastructure that powers the nation's electrical power grid. Making cyberinfrastructure as easy to use as electrical power is no mean feat, and Indiana University is involved in the TeraGrid in two ways. Pervasive Technology Labs, particularly Science Director Dennis Gannon and CGL Director Geoffrey C. Fox, have significant funding to develop the interface and access tools that will make the TeraGrid accessible to the general U.S. research community. University Information Technology Services is a resource provider for the TeraGrid—delivering supercomputer capacity, massive data storage systems, and other facilities and support for operation of the TeraGrid. Together, Pervasive Technology Labs and UITS have secured a total of $7,034632 in grant funding from the National Science Foundation as a result of participation in the TeraGrid. Most recently, UITS has initiated a $100,000 subproject to implement the award-winning IU Knowledge Base as an online help system for the TeraGrid.

- **I-Light 2.** Governor Mitch Daniels announced on November 1, 2005, that the I-Light optical fiber network project will be extended to the state's colleges and universities to support their research and education programs. This $8.2 million project is heavily influenced by the desire to enhance the state's cyberinfrastrucure. A critical factor in enhancing that statewide cyberinfrastructure will be efforts to make more generally available access to tools provided by Indiana University and Pervasive Technology Labs.



3-D visualization of chemical proteins done by the Community Grids lab for the Big Red Supercomputer ribbon cutting ceremony.

Collaborative Activities

- **Big Red supercomputer.** Indiana University's Big Red supercomputer was publicly announced in April, and made its debut appearance in 23rd place on the Top 500 list of the most powerful supercomputers in the world. Big Red is the largest supercomputer ever installed in the State of Indiana—with a peak theoretical capability of 20.4 TeraFLOPS (that is, 20.4 trillion mathematical operations per second). Big Red is the largest academic supercomputer in the United States, and when connected to the TeraGrid will also be the largest supercomputer functioning as part of the TeraGrid. The use of open-source software developed by the Open Systems Lab is fundamental to IU's operation of this massive new supercomputer. (Press releases about Big Red are included in Appendix 9, June 28 Section.) The acquisition of Big Red was funded partially through university general funds and partially through funds provided by the Lilly Endowment, Inc., to Indiana University via the Indiana METACyt Initiative. It now falls to UITS and Pervasive Technology Labs to deploy and support Big Red in ways that advance the life sciences strategy of Indiana University—yet another example of the role of computer science and information technology as enablers of the university's life science strategies. A chemical informatics demonstration organized by the Community Grids Lab was the highlight of the Big Red ribbon- cutting ceremony.

Major Conferences and Events

TeraGridConference. The TeraGrid held for the first time ever a conference about the TeraGrid involving the people developing the TeraGrid as well as its intended users. This inaugural TeraGrid conference, held in Indianapolis in June, was collaboratively organized and managed by Indiana and Purdue Universities, with UITS and Pervasive Technology Labs playing important roles. The conference has been hailed by many of the leading computational scientists in the United States and Europe as a breakthrough in fostering important and timely dialogue about the national strategy on cyberinfrastructure. We expect tangible and important enhancements in the utility of the TeraGrid during the coming year, as a direct result of the discussions held at the conference. One element of the TeraGrid conference was an evening reception in the Informatics and Communications Technology Building (ICTC) that featured new PTL and UITS facilities. PTL and the ICTC made tremendously positive impressions on the hundreds of participants in the TeraGrid conference.

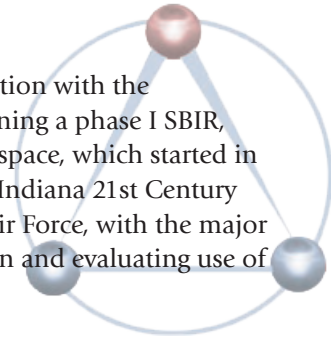
IV. ECONOMIC DEVELOPMENT

Economic development outcomes of PTL and the PTL Capital Investment Fund continue to enhance the innovation economy of the State of Indiana and the PTL economic development agenda is showing real strength. There are six spinoff companies related to PTL labs—one per lab. The companies in which the PTL Capital Investment Fund has made investments are growing, and sales of those companies should result in return of initial investments and profits back to the fund, for subsequent reinvestment within the State of Indiana. It is commonly held that one of the important factors limiting the rate of growth of the high-tech economy in Indiana is the relative paucity of seed and start-up funds. The PTL Capital Investment Fund is at work changing this, to the benefit of the State.

Recent activity by PTL-related spin-off companies, and companies in which the PTL Capital Investment Fund has made investments, are summarized in the following pages.

New Activity by PTL-affiliated Spin-off Companies

- **Veterisoft, Inc. (created by and affiliated with the Open Systems Lab).** Veteris, Inc., changed its name to Veterisoft. The company plans to market a tool that will support and improve the collaborative development of software. Veterisoft, Inc., has completed a detailed business plan and a beta test version of the "SourceHaven" software development tool. SourceHaven is now available for purchase and is already serving several customers.



- **Anabas, Inc. (affiliated with the Community Grids Lab).** In collaboration with the Community Grids Lab, Anabas has had a very successful period. After earning a phase I SBIR, the company received a $750,000 phase II award with CGL and Ball Aerospace, which started in June 2006. Anabas also obtained $100,000 in a matching grant from the Indiana 21st Century Research and Technology Fund and started a partnership funded by the Air Force, with the major corporation SAIC. Anabas is continuing to develop its e-Textile application and evaluating use of GlobalMMCS technologies.

- **EnVizable LLC (affiliated with the Visualization and Interactive Spaces Lab).** EnVizable is still in its early stages and is working to complete product development. The company anticipates significant progress in the coming period as it moves forward in developing a comprehensive business plan.

- **SGC Technologies, LLC.** SGC Technologies continues to develop and market its FileSHARE inter-enterprise data exchange technology. In April of 2006, the company rolled out the latest version of the product and upgraded existing customers to the standard. As of June 2006 the company had completed its first sale to an outside entity and currently is in negotiations with another end-user sale, as well as two development and marketing partner companies. The development and marketing alliances will allow SGC access to markets beyond SGC's core competencies of higher education and medical applications.

Companies in which the PTL Capital Investment Fund has made investments:

- **The Haelan Group.** The Haelan Group now has over 50 employees. The Haelan Group received significant note at the 2006 Techpoint Mira Awards ceremony, where they were finalists for awards in several categories. The Haelan Group has just received a major contract to provide services for all employees of the State of Indiana and they recently rewrote and updated all their software for management of health care.

- **Dynomed, Inc. (now part of Chartlogix, Inc., of Salt Lake City).** Dynomed has been acquired by Chartlogix, Inc., of Salt Lake City and is continuing development of their software and products.

V. PTL FELLOWS PROGRAM REPORTS

Collaboration among researchers is always at the heart of scientific discovery and innovation. It is with this in mind that Pervasive Technology Labs launched its Fellows Program in 2003. The program paired a PTL lab or labs with Indiana University researchers from outside and related disciplines to collaborate on advanced projects involving pervasive technology.

PTL Fellows Program candidates prepared proposals describing intended project work and outlining ways in which they would collaborate with PTL researchers. Fellows were selected from the highest quality proposals. Two rounds of awards were made in 2004 and 2005 with a total of eight fellows being selected to receive funding in support of their proposed collaboration.

The Fellows Program concluded in 2006 and each of the fellows has reported on the results of their project work and collaborations. Many fellows enjoy ongoing partnerships with PTL labs beyond their fellowship work and several projects started during the fellowships are highly successful and ongoing.

PTL fellows published numerous scholarly works and obtained a respectable amount of additional grant funding related to their various fellowship projects. Several students participated in fellowship work and were mentored by PTL fellows.

Reports follow from each of the PTL fellows which detail research projects and intellectual output. For a complete listing of all related publications, funded research, and leadership activity for the PTL fellows please see the full version of this report at www.pervasive.iu.edu.

Dr. Katy Börner

Assistant Professor, School of Library and Information Science

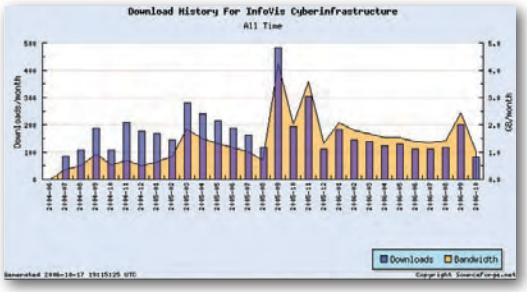
Fellows Project Title: "Cyberinfrastructure for Networks Research"
PTL Partners: Worked with all six PTL labs

Summary of Key Fellowship Activities and Accomplishments:

Dr. Börner's fellowship allowed her to develop a data-code-computing infrastructure used in data mining, modeling and visualization research and education, research that related in various ways to work being done in all six Pervasive Technology Labs. The infrastructure, called Information Visualization Cyberinfrastructure (IVC), is now being used to conduct basic and applied research in data mining, modeling, and visualization both within Indiana University and by outside researchers. Dr. Börner's application has proven to be very successful and has been downloaded nearly 4,000 times since June 2004.

IVC has also proven to be valuable in student education and is used by Dr. Börner in teaching two graduate-level courses, Information Visualization, and Structural Data Mining and Modeling.

- Dr. Börner produced ten (10) publications and presentations related to her fellowship work



- Since June 2004, the Information Visualization Cyberinfrastructure (IVC) software described above has been downloaded 3,945 times. This software is available as open source via **http://sourceforge.net/projects/ivc**.

- The Information Visualization CyberInfrastructure (IVC) software frame extends the original Information Visualization Repository (Börner & Zhou, 2001). It is a set of libraries that provide a simple and uniform programming-interface to algorithms and user-interface to end-users by leveraging the power of the Eclipse Rich Client Platform (RCP). **http://iv.slis.indiana.edu/sw**

- Dr. Börner received support for 13 funded projects related to her fellowship work. Total funding for these projects was in excess of $6 million.

Dr. James A. Glazier

Professor of Physics; Adjunct Professor of Informatics and Biology;
Director, Biocomplexity Institute

Fellows Project Title: "Development of Biocomplexity Computational Environments"
PTL Partners: Community Grids Lab, Open Systems Lab, Scientific Data Analysis Lab

Summary of Key Fellowship Activities and Accomplishments:

Fellowship activities pursued by Dr. Glazier focused largely on the development and deployment of an improved version of the open-source software package CompuCell 3D. The software, which was previously developed by Dr. Glazier and collaborators from Notre Dame University, is used for simulation of biological development. Rewriting and improvement of the software was led by Christopher Mueller, a graduate research assistant who was co-supervised by Dr. Glazier and Dr. Lumsdaine of the Open Systems Lab. Randy Heiland and Charles Moad of the Scientific Data Analysis Lab also contributed to the project. The current version of CompuCell 3D, now hosted on the SimTK Web site, has a more intuitive graphical user interface (GUI) and greatly enhanced flexibility and documentation, and has attracted a substantial number of dedicated users. Work on the CompuCell 3D project led to the submission of a joint grant submission to the National Institutes of Health (NIH) by Dr. Glazier and Randy Heiland.

In addition to the software development component of the project, Dr. Glazier's fellowship supported substantial research in several areas of the medical and life sciences. This work led to a successful multi-institution proposal, jointly funded by the National Science Foundation (NSF) and the NIH. A number of additional NIH and NSF grant proposals on which Dr. Glazier collaborated with Dr. Lumsdaine and Dr. Fox were also supported by the fellowship work. Fellowship projects provided support and learning opportunities for a number of graduate students and postdoctoral researchers, and CompuCell3D was a core educational component of Dr. Glazier's class on Mathematical Biology which was offered to a group of advanced undergraduate and graduate students.

- Dr. Glazier produced seventeen (17) related publications during the course of his fellowship.

- Dr. Glazier had three related invention disclosures and software releases:
  CompuCell 3D https://simtk.org/home/compucell3d
  http://biocomplexity.indiana.edu/jglazier/courses/p548/

- Dr. Glazier received support for six (6) funded projects related to his fellowship work. Total funding for these projects was in excess of $1.7 million.

Dr. Andrew Hsu

Professor of Mechanical Engineering

Fellows Project Title: "The Development of RF Chip Based Non-invasive Monitoring System for Implantable Medical Devices"
PTL Partner: Visualization and Interactive Spaces Lab

Summary of Key Fellowship Activities and Accomplishments:

Dr. Hsu's fellowship supported research activities related to fluid measurement and simulation, including computer simulation of a hydrogen fuel cell and hydrogen storage at the nanoscale. He also worked to establish an international collaboration with the Chinese Academy of Science to test an RF chip with pressure sensors, which has lead to an ongoing partnership. During his fellowship, Dr. Hsu developed and successfully tested an experimental apparatus to illustrate the concept. Work will continue beyond the life of Dr. Hsu's PTL Fellowship in order to miniaturize the pressure sensor and RF chip. Dr. Hsu conducted additional research in an attempt to extend the application of RF-based pressure sensors to aerodynamic measurement of flows over helicopter blades, where miniaturization is not required. He found application of RF chip technology can significantly simplify the procedure and improve the accuracy or micro-rotor testing, as micro-rotor data and performance can be monitored remotely without wiring complications. Hsu asserts that, compared to sensors currently used in the aerospace industry, the application of the RF-CMOS technology offers significant advantages, and he credits his fellowship to advancing this research.

The PTL Fellowship supported the development of a proposal titled "A Vortex-Dynamics Apprach and an RF-CMOS Scheme for the Aerodynamic Design and Testing of Micro-Rotors" which is currently under review by the U.S. Army. The fellowship also supported one student who earned a master's degree during the course of the fellowship.

- Dr. Hsu produced a total of five (5) publications and presentations related to his fellowship work.

- Dr. Hsu received support for two (2) funded projects related to his fellowship work. Total funding for these projects was in excess of $850,000.

Dr. Brian King

Assistant Professor of Electrical and Computer Engineering

Fellows Project Title: "Security in Wireless Networks and Personal Devices"
PTL Partner: Advanced Network Management Lab

Summary of Key Activities and Accomplishments:

Dr. King's PTL Fellowship project focused on wireless security and lightweight/low complexity devices. During his fellowship, Dr. King published two important results in elliptic curve cryptography (ECC), a well-recognized public key cryptosystem that is preferred for wireless networks. His PTL Fellowship also allowed Dr. King to work with students to develop several wireless applications in the areas of mobile e-commerce, RFID security, and the use of permutation polynomials as a cryptographic tool.

The RFID research resulted in two published works and several other papers submitted and pending publication. It was also the basis for a pending National Science Foundation grant proposal concerning the security of RFID and ubiquitous devices. One student completed a master's thesis related to the fellowship work and another master's student, Xiolan Zhang, who was fully funded by the fellowship, placed third in a graduate research contest conducted by the Sigma Xi organization, in which most of the competitors were Ph.D. candidates.

- Dr. King produced nine (9) publications and presentations related to his fellowship work.

Dr. David M. Koceja
Associate Dean for Research, School of Health, Physical Education, and Recreation

Fellows Project Title: "E-Health and e-Sports for All: A Collaboration with Beijing Sport University"
PTL Partner: Community Grids Lab

Summary of Key Fellowship Activities and Accomplishments:

The goal of Dr. Koceja's fellowship work was to employ recent advances in hardware and software technologies such as voice-over IP and Web services to build an electronic infrastructure e-global community with a sister university, Beijing Sport University. This community would allow for an open exchange of knowledge between scholars at the two universities in areas such as sports performance, health and medicine and, Olympic planning. The School of Health, Physical Education, and Recreation (HPER) at Indiana University has enjoyed an ongoing academic relationship with Beijing Sport University dating back to 1989. On a yearly basis, HPER has sent scholars to Beijing to deliver scientific talks, lectures, and demonstrations, and Beijing Sport University has likewise sent its own scholars to visit Indiana University. Dr. Koceja and his assistants, Shaowen Bardzell and Hongwei Guan, worked with Dr. Geoffrey Fox and his Community Grids Lab members to evaluate the technology infrastructure of Beijing Sport University in order to understand the computer interface and the mechanics behind the technology, and to begin the process of linking the universities in real time. This is an ongoing project and collaboration, and the groups involved are still in the process of linking the two universities.

Dr. Koceja's project supported the work of one graduate student and yielded a submission to the National Institutes of Health titled "Tai Chi and Balance," which proposed to use Community Grids Lab technology to develop a working laboratory in Beijing to research motor control and balance in the elderly.

Dr. Sean Mooney

Assistant Professor, Medical and Molecular Genetics

Fellows Project Title: "Visualization and Analysis of Genomic and Protein Structural Data"
PTL Partner: Scientific Data Analysis Lab

Summary of Key Fellowship Activities and Accomplishments:

During his fellowship, Dr. Mooney worked closely with Randy Heiland of the Scientific Data Analysis Lab to develop innovative methods for the visualization and analysis of genomic and protein structural data. Together, Mooney and Heiland created a suite of Web services and extensions to traditional molecular modeling tools such as UCSF Chimera and Delano Scientific PyMOL. Since being published in the journal *Nucleic Acids Research*, their successful MutDB plugin, which integrates mutation data with protein structural data, has been downloaded more than 200 times. Their follow-up project, the S-BLEST plugin, was recently published in *BMC Structural Biology*.

Also during his fellowship, Dr. Mooney co-founded the Indiana Biomedical Entrepreneur Network and served on organization committees for several related conferences. Three undergraduate students assisted in his fellowship work and one student earned a master's degree.

- Dr. Mooney produced three (3) publications and presentations related to his fellowship work.

- Dr. Mooney had two related invention disclosures and software releases:
  MutDB Software© (http://mutdb.org/)
  Lifescience Web Software© (http://www.lifescienceWeb.org/)

- Dr. Mooney received support for two (2) funded projects related to his fellowship work.

Dr. Yvonne Rogers

Professor of Informatics, Information Science, and Cognitive Science

Fellows Project Title: "Promoting Integrated and Collaborative Learning through the Design and Application of Pervasive Technologies"
PTL Partners: Visualization and Interactive Spaces Lab, Open Systems Lab

Summary of Key Fellowship Activities and Accomplishments:

Dr. Rogers' fellowship work focused on the development of pervasive technologies to promote novel forms of teaching and learning that moved beyond the traditional classroom. Dr. Rogers collaborated extensively with Pervasive Technology Labs researchers Kay Connelly and M. Pauline Baker as well as with another PTL Fellow, Lenore Tedesco, and her work supported the ongoing outreach, environmental, and education programs of Pervasive Technology Labs, IUB, and IUPUI. The goal of her work was to investigate how pervasive environments, specifically wi-fi and sensor-based technologies, combined with mobile and stand-alone computational devices, could bridge informal and formal learning contexts and enable students to connect classroom knowledge and hypotheses to real-world settings.

Fellowship research conducted by Dr. Rogers resulted in a number of prototype systems using MERL's tabletop, phidget, and RFID technologies that targeted health education and collaborative learning. In addition, a robust mobile PDA application called LillyPad was created to facilitate data collection and inquiry activities by teams of scientists and students working in outdoor environments. The LillyPad is now being used as part of the Lilly Arbor Project to help students and scientists record, learn, and reason about an experimental floodplain reforestation site. Studies have demonstrated that the device is successful and beneficial to the learning process. (See http://www.slis.indiana.edu/faculty/yrogers/rprojects_lillypad.htm).

During her fellowship, Dr. Rogers co-taught a course on Pervasive Computing with PTL researcher Dr. Kay Connelly and she mentored a number of student design projects. One student completed a Ph.D. and three students completed master's degrees under her supervision.

- Dr. Rogers produced a total of ten (10) publications and presentations related to her fellowship work.

Dr. Lenore Tedesco
Director, Center for Earth and Environmental Science (CEES)
Associate Professor Department of Earth Sciences

Fellows Project Titles: "An Integrated Environmental Monitoring Network and Its Visualization" and "RAPID: Remotely Accessible Personal Information Display Bridging the Gap between the Field and the Laboratory to Synthesize Environmental Data"
PTL Partner: Visualization and Interactive Spaces Lab

Summary of Key Fellowship Activities and Accomplishments:

Over the course of her two-year fellowship, Dr. Tedesco worked closely with Dr. Baker of the Visualization and Interactive Spaces Lab as well as with another PTL Fellow, Dr. Yvonne Rogers, on two separate but related projects. The first project, "An Integrated Environmental Monitoring Network and Its Visualization," developed and used an integrated network of sensors throughout Marion County to collect and visualize real-time data generated from a spectrum of dynamic ecosystems. The technologies were designed to aid in science education across a range of audiences, with particular emphasis on young people. As part of this project, CEES and the VIS Lab developed an interactive "Watching Your Watershed" display for the Indiana State, Museum in which the PercepTable graphically displays Indiana watersheds while the user initiates one of five "real-life" storm events that affected the state. The display gives graphical feedback of water volume as it passes through the watershed and into flood zones. The second project, "RAPID: Remotely Accessible Personal Information Display Bridging the Gap between the Field and the Laboratory to Synthesize Environmental Data," was highly successful and focused on the development of hand-held PDA technology called the LillyPad, which is described in Dr. Yvonne Rogers' report.

Tedesco's fellowship helped to support the work of four undergraduate students and resulted in a paper about the LillyPad technology that is currently under peer review. She continues to partner with both Dr. Baker and Dr. Rogers and she has recently received additional funding to launch a science education program that builds on the technologies the group developed during her fellowship. An additional grant related to the research is pending.

- Dr. Tedesco produced eight (8) publications and presentations related to her PTL Fellowship.

- Dr. Tedesco was awarded one grant totaling $270,000 related to her fellowship work.

VI. PTL OUTREACH ACTIVITIES

In light of recent National Assessment for Education Progress (NAEP) results, the State of Indiana has identified the ongoing improvement of Science, Technology, Engineering, and Mathematics (STEM) education as an important priority in its public schools. Indiana Superintendent of Public Instruction Suellen Reed commented in a May 2006 news release, "A strong understanding of the sciences is key to our students' education and our economic competitiveness as a state…" Indiana University has recently increased activity in this area, announcing this spring the establishment of a new Institute for Science, Technology, Engineering, and Mathematics Education (ISTEME), with a goal to improve Hoosier literacy in STEM education for K–12 students throughout the state.

ANML Researcher David Ripley teaches Indiana students about the Indy Robotics Vehicle (IVR) at an outreach event held at the 2006 Intel Interntaional Science and Engineering Fair in Indianapolis in May.

Outreach has always been a natural part of work at Pervasive Technology Labs due to the PTL mission to attract, encourage, educate, and retain the workforce of tomorrow for the State of Indiana and educate the residents of the state generally. PTL has pursued community outreach opportunities, from teaching children simple programming skills to educating families about risks associated with online social networking Web sites.

To coordinate with the ISTEME and statewide efforts to improve STEM education, the labs are now set to launch a formal Pervasive Technology Labs Community Outreach Program. The program will serve to add structure to and increase PTL's outreach activities by working directly with Indiana educators to bring technology education programs and demos to area classrooms. Our scientists will work with teachers to design talks, tours, and demos relating to PTL research projects in order to complement classroom instruction and expose Indiana young people at an early age to scientific concepts and potential science careers.

Children visiting the ISEF IRV demo received photos of themselves with the vehicle as part of a PTL Outreach Program event sponsored by the ANML.

VII. OPERATIONAL ACTIVITIES

Management of Pervasive Technology Labs continues to evolve as the leadership of the university evolves. Professor Michael A. McRobbie has, during this reporting period, officially taken on the duties of interim provost of Indiana University. In the wake of this change, Professor Bradley C. Wheeler has been named Acting Chief Information Officer of Indiana University. With this change, CIO Wheeler has taken on a direct role in working with Science Director Dennis Gannon and Chief Operating Officer Craig Stewart in leading Pervasive Technology Labs. With Wheeler's deep involvement in community source software projects such as the Sakai Consortium and the Kuali project, this means yet another opportunity for deeper collaboration between Pervasive Technology Labs and the Office of the Vice President for Information Technology and CIO, and with the rest of UITS. For example, the greater involvement of CIO Wheeler with PTL should directly impact and enhance the interactions and collaborations between UITS and the Open Systems Lab.

Management structure within Pervasive Technology Labs continues to be streamlined and made more effective. All central supporting staff within PTL now report to Therese Miller, Operations Manager of Pervasive Technology Labs. Ms. Miller reports directly to COO Stewart, and is Stewart's sole direct report from PTL. This considerably enhances PTL's ability to take advantage of Miller's leadership skills and experience.

During this reporting period, Daphne Siefert-Herron began her new role as PTL Information Manager. Ms. Siefert-Herron's impact on PTL has already been beneficial, as quality and comprehensiveness of PTL reports continues to improve. More important, Ms. Siefert-Herron's efforts to enhance the public profile of PTL have paid off handsomely—as evidenced by the more than 30 press releases and articles that appeared about PTL during this reporting period.

VIII. PROGRESS AGAINST MILESTONES SET IN THE INDIANA PERVASIVE COMPUTING RESEARCH INITIATIVE GRANT PROPOSAL

At the end of the 2005/2006 fiscal year, it seems appropriate to look back to the initial proposal to the Lilly Endowment, Inc., for the Indiana Pervasive Computing Research Initiative, and analyze progress against the milestones set in that proposal.

The result is striking: PTL can claim full accomplishment and continued progress in many of the areas for which milestones were defined, and significant progress against almost all of the milestones set out in that proposal. This section summarizes the milestones set out in the initial IPCRES proposal and charts progress against those milestones.

Overall PTL progress against the milestones set in 1999 is detailed below (in many cases, the text of milestones has been updated to reflect changes in terminology or organizational structure that have transpired since 1999).

- **Six PTL Laboratories operating. Accomplished.** This milestone was achieved in May, 2003.

- **Technology Transfer and Economic Development Advisory Board is established. PTL Economic Development Office established. Significant progress.**

The PTL Capital Investment Fund steering Committee has met regularly for years, and $1,750,000 of the initial $2,000,000 investment fund has been invested. The economic development activities of PTL are now led directly by staff of the Indiana University Research and Technology Corporation. The PTL economic development effort overall is making good progress. In order to obtain enhanced advice regarding technology transfer and economic development, PTL is currently assembling a new Technology Transfer and Economic Development Advisory Board, which will provide particular focus specific to technology transfer by PTL (prior to this, the IU Information Technology Advisory Council has provided significant advice related to technology transfer generally as regards IT and IU, and will continue to do so at a strategic level).

- **PTL influencing state economic development policy and funding for investment in information technology. PTL Capital Investment Fund fosters increase in availability of private sector capital to assist technology start-ups. Accomplished.**

IU Interim Provost Michael A. McRobbie, CIO Bradley C. Wheeler, and COO Craig A. Stewart are deeply involved in policy-setting discussions with the Indiana Economic Development Corporation in regard to state economic development policy on information technology. For example, PTL CEO and IU Interim Provost Michael A. McRobbie was instrumental in gaining State approval for the I-Light2 project. I-light2 will expand the I-light network throughout the state of Indiana's higher education community. Provost McRobbie's efforts to make the case for I-Light2 were greatly aided by the accomplishments of PTL. Technology developed by PTL will enhance the value of the state's cyberinfrastructure based on the I-Light network and PTL network engineering and cybersecurity innovations will be important in enabling Indiana University to oversee the safe and effective operation of the expanded I-light system.

Involvement of PTL and UITS with the state's top leadership has been positive and direct. Below is a picture of Governor Mitch Daniels with PTL CEO and IU Interim Provost Michael A. McRobbie and PTL COO Craig Stewart visiting the ICTC building on the IUPUI campus in February of 2006. This highly productive visit included discussion of PTL and UITS in enhancing economic growth in the state.

The PTL Capital Investment Fund has had direct and indirect impacts on the availability of private sector capital to assist technology start-ups. The PTL Capital Investment Fund has injected $1,750,000 directly into the Indiana economy a significant boost to venture capital start-up funding in the state. These funds have been leveraged to bring in additional funding in support of start-ups to the state—these additional investments total more than $1,860,000.

Photo by John Herrin.

- **Continuing growth in number of information technology companies and technology workers in Indiana. Significant progress.**

A report just issued by the Brookings Institution shows that Indianapolis had the highest job-growth rate among 25 Midwestern metropolitan areas (*Inside Indiana Business*, July 27, 2006.) According to the report, the city topped the list in net gain of "advanced service jobs" such as engineering and technology, indicating a significant change in the tide. It is PTL's plan to produce an analysis that will carefully look at the high-tech economy of Indiana as compared to other states, and determine whether Indiana has done relatively better or less well than other states. This report will also analyze the impact of PTL on the Indiana economy in some detail. This report will be produced during the 2006–07 academic year.

- **School of Informatics has over 160 graduate students and over 1,400 undergraduates. State retaining high percentage of technology graduates. Significant progress in enrollment at the undergraduate level, enrollment goal exceeded at the graduate level. Significant progress in retention of technology graduates.**

Growth in undergraduate and graduate students in the School of Informatics has been strong. The School of Informatics had, during the 2005–06 academic year, a total of 1,098 undergraduate majors and 406 graduate students, for a total of 1,504 majors at the undergraduate and graduate level combined.

The Indiana University School of Informatics reports that its average rate of retention of students within the state of Indiana since inception has been 48%. This figure has fluctuated somewhat from year to year, with what has turned out to be a slight downward trend in retention of graduates within the state. This is a result of a factor not predicted during the writing of the initial IPCRES proposal: The quality of the IU School of Informatics and its graduates has become so widely recognized that there is fierce competition by employers for graduates. This has created significant pressure for graduates to take employment outside of Indiana. An overall retention rate of 48% is a tremendous success and means that hundreds of professionals educated by the IU School of Informatics are at work in Indiana as part of its high-tech economy.

- **Increased numbers of relationships and memoranda of agreement between PTL and industry continues to rise. Accomplished.**

There are now more than 10 formal relationships between PTL and the private sector, as detailed in the table below. As important as the number of relationships is the magnitude of these relationships. The Community Grids Lab has set a new high-water mark in securing a major contract with Microsoft, Inc. PTL continues to cultivate such relationships as part of its strategy for sustainability of the Labs.

- **The Indianapolis region is nationally recognized as a significant emerging technology region. Accomplished.**

We have not found a good way to measure progress against this metric in a clear objective fashion, but it is plainly evident that Indianapolis, and the state of Indiana generally, are regarded as significant areas of development of new technologies. Anecdotal evidence includes the following:

- o Indianapolis is routinely selected to host major technology conferences, such as the recent TeraGrid conference held in the city.
- o The Global NOC (network operations center), located in Indianapolis, is known nationally and internationally as the operating hub for the fastest networks in the United States, and the high speed research network connections between North America and other continents.
- o Indiana has received widespread note as the home of the (currently) fastest academic supercomputer in the United States—and one of the 25 fastest supercomputers in the world.
- o Indiana is one of nine national partners in the NSF-funded national TeraGrid project—the NSF's flagship effort to build a national cyberinfrastructure
- o The activities of Techpoint—which often feature PTL prominently—receive significant attention nationally.
- o The IU School of Informatics—the first such school in the United States—has grown in stature to be recognized as a national and international role model.
- o IU-led displays at the national Supercomputing Conference are regarded by many participants as a "must see" display at the conference.
- o The most compelling objective evidence is the Brookings report mentioned above, citing Indianapolis as having the top job growth rate among major Midwestern metropolitan areas from 1995 to 2005.

PTL will continue to seek objective ways to measure the perception of Indianapolis and the state of Indiana. Unfortunately, the American Electronics Association has not created a new version of its "CyberCities" report since 1998—unfortunate, as this report was one of the best ways to measure progress objectively.

- **16 or more IPCRES researchers with School of Informatics appointments. Accomplished.**

A total of 17 Pervasive Technology Labs-affiliated researchers have appointments in the School of Informatics and additional appointments are pending.

IX. APPENDICES

APPENDIX 1: PATENTS FILED BY PERVASIVE TECHNOLOGY LABS

Appendix 1: Patents Filed by Pervasive Technology Labs

Tech No.	Tech Name	PTL Director	Description	Status	Comments
05021	Compression scheme for improved efficiency of sparse matrix computations.	Lumsdaine	Encoding scheme that reduces memory requirements necessary to store and access matrices.	Active	Provisionsal Patent Filed
06163	Single-Packet Radiolocation of 802.11 Wireless Sources	Wallace	Apparatus consists of a set of sixteen directional antennas, a radio receiver a power-measuring device, and data collection equipment.	Active	Provisional Patent Filed

For a complete listing of all Pervasive Technology Labs disclosures, online services, hardware applications, publications, and presentations, please visit: **www.pervasive.iu.edu.**

APPENDIX 2: TECHNOLOGY DISCLOSURES FILED BY PERVASIVE TECHNOLOGY LABS

Appendix 2: Technology Disclosures Filed by Pervasive Technology Labs

***Items in bold indicate new for the reporting period 1/06 to 6/06.**

Tech No.	Tech Name	PTL Director	Description	Status	Comments
06218	**Narada Brokering**	**Fox**	**A CGL Open-Source project that researches fundamental issues pertaining to distributed middleware systems.**	**New**	
07003	**SMEApp**	**McMullen**	**Diagnostic software that learns from expert actions.**	**New (at RTC) intake stage)**	
06163	Single-Packet Radiolocation of 802.11 Wireless Sources	Wallace	Apparatus consists of a set of 16 directional antennas, a radio receiver, a power-measuring device, and data collection equipment.	Provisional Patent Filed	
06088	ArtXplore, Location Tracking System	Baker	Location tracking system for ArtXplore, a Digital Museum Experience, and some of the overall system architecture and data design.	Non-exclusive license	
06020	ConceptGCC	Lumsdaine	Extends the existing, O/S GNU C++ compiler with language support generic programming.	Open Source	
05119	Navigating New Spaces	Baker	Application allowing Indianapolis Museum of Art (IMA) visitors to browse the IMA collection on the PercepTable.	On same license 0360	

Appendix 2: Technology Disclosures Filed by Pervasive Technology Labs (continued)

Tech No.	Tech Name	PTL Director	Description	Status	Comments
05118	PhotoBoard	Baker	Prototype application for examining large groups of digital images and assigning them to categories.	On same license as 0360	
05105	Type checker prototype extended generic C#	Lumsdaine	Prototype implementation of a type checker and translator to standard Generic C# for some extended features we propose for that language.	Open Source	
05101	Open MPI	Lumsdaine	Parallel run-time environment and message passing system that is an implementation of the Message Passing Interface (MPI) standard.	Open Source	
05099	Web services and applications for structural visualization of mutation data	Heiland/Mooney (PTL Fellow) Collaboration	Software providing Web services functionality to access and display genetic mutation data.	Active	
05097	Information Visualization Cyberinfrastrcture Database	Borner (PTL (Fellow)	Database of scholarly work that aims to serve researchers and technologists intersted in the large-scale analysis, modeling, and' visualization of literature data sets.	Actice	

Appendix 2: Technology Disclosures Filed by Pervasive Technology Labs (continued)

Tech No.	Tech Name	PTL Director	Description	Status	Comments
05095	Information Visualization Cyberinfrastructure Software Framework	Borner (PTL Fellow)	Framework designed to facilitate the integration of data analysis, modeling and visualization algorithms into a unified system.	Open Source	
05091	MutDB	Mooeny (PTL Fellow)	Database, sofware and Web site suitable for genome annotation.	Active	
05090	S-BLEST structure based local environment search tool	Mooney (PTL Fellow)	Software that rapidly finds structurally similar sites in protein structures within a database and identifies structural environments associated with a given function.	Active	Copyright Application
05085	Parallel Boost Graphic Library	Lumsdaine	Library for parallel computation of graph (or network) data structures.	Open Source	
05056	Indiana University Case-Based Reasoning Framework (IUCBRF)	McMullen	Framework to facilitate the development of case-based reasoning (CBR) sytems.	Open Source	

Appendix 2: Technology Disclosures Filed by Pervasive Technology Labs (continued)

Tech No.	Tech Name	PTL Director	Description	Status	Comments
05052	Traffic-Based Mechanism Ordering Search Results	Wallace	Tool to analyze traffic on a data network to determine the requested and referring URLs for HTTP requests on the World Wide Web.	Active	
0502	Compression scheme for improved efficiency of sparse matrix computations.	Lumsdaine	Encoding scheme that reduces memory requirements necessary to store and access matrices.	Active	Provisional Patent Filed
05009	Make a Meal Auto-Sensing Interface for Nutrition Education	Baker	Computer interface that uses physical objects for teaching about food nutrient values by detecting what food items are present on a tray.	Hold	
04074	Matrix Template Library version 1-2, iterative Template Library versions 1-4	Lumsdaine	Generic library written in C++ for basic linear algebra computations.	Open Source	
04073	Boost Graphic Library	Lumsdaine	Provides algorithms and data-structures concerning graphs (nodes) and edges.	Open Source	

Appendix 2: Technology Disclosures Filed by Pervasive Technology Labs (continued)

Tech No.	Tech Name	PTL Director	Description	Status	Comments
04072	Slashtmp: Method to convey authorization to one outside of the party's administrative domain	Wallace	Method to create a unique Uniform Resource Locator (URL) that can be used to authorize a specific Web-based action for a party outside the user's administrative domain.	Non-Exclusive License	
04067	Boost MultiArray	Lumsdaine	Generic library of multi-dimensional arrays.	Open Source	
04020	Boost enable if	Lumsdaine	General purpose tool for controlling template function overloading and class template specializations in C++.	Open Source	
04009	MPI.NET (P/Invoke Bindings Subset)	Lumsdaine	Set of bindings from C# to the MPI standard allowing high-performance parallel communications from programs written in C# and other CLI languages.	Open Source	

Appendix 2: Technology Disclosures Filed by Pervasive Technology Labs (continued)

Tech No.	Tech Name	PTL Director	Description	Status	Comments
0397	Narada Brokering	Fox	Distributed middleware to handle a large number of clients. Also supports a variety of interactions such as centralized, distributed, and P2P.	Open Source	
0383	Distribted Shared Memory with Just-In-Time Compilation	Lumsdaine	Just-in-time compilation to effect distributed shared memory functionality in a distributed memory (cluster) virtual machine.	Hold	
0361	MUTT (Multi-User Tool Tracking)	Baker	Software to track and decode user interaction with physical objects used in a user interface without wires, mouse, or keyboard.	Active	
0360	PercepTable™	Baker	Device for display and interaction with computer-generated graphics. Graphics are projected onto a horizontal table and users interact with display using tools tracked by video camera.	Non-exclusive License	

Appendix 2: Technology Disclosures Filed by Pervasive Technology Labs (continued)

Tech No.	Tech Name	PTL Director	Description	Status	Comments
0352	LAM-MPI	Lumsdaine	MPI programming environment and development system for heterogeneous computers on a network.	Open Source	
0349	SourceGrid	Lumsdaine	Portal for software project managers that is a collection of compatible development and testing portlets.	Exclusive License	
0314	Spoofwatch	Wallace	SNORT plug-in that detects IP packets using spoofed sorce addresses.	Open Source	
0313	Tsunami	Wallace	Implementation of file transfer protocol of the same optimized to transfer large files over long-distance network links where there may be packet loss due to errors.	Open Source	

For a complete listing of all Pervasive Technology Labs disclosures, online services, hardware applications, publications, and presentations, please visit: **www.pervasive.iu.edu.**

APPENDIX 3. PUBLICATIONS BY PERVASIVE TECHNOLOGY LABS —SINCE INCEPTION

Open Systems Lab Publications

A complete list of publications since the inception of PTL appears below. For a list of presentations please view the complete 78-month report at **www.pervasive.iu.edu**.

Abrahams, D., & Siek, J. (2001, October). Policy Adaptors and the Boost Iterator Adaptor Library. Paper presented at the Second Workshop on C++ Template Programming.

Abrahams, D., Siek, J., & Witt, T. (2003). Iterator Façade and Adaptor (No. N1455-03-0038, ISA/IEC JTC 1): Information Technology Subcommittee SC22 Programming Language C++.

Abrahams, D., Siek, J., & Witt, T. (2003). New Iterator Concepts (No. N1477-03-0060, ISO/IEC JTC 1): Information Technology Subcommittee SC22 Programming Language C++.

Albrecht, A., Gottschling, P., & Naumann, U. (2003). Markowitz-type Heuristics for Computing Jacobean Matrices Efficiently. Paper presented at the International Conference on Computational Science, St. Petersburg, Russia.

Albrect, A., Gottschling, P., & Naumann, U. (2002). Logarithmic Simulated Annealing for Optimal Derivative Code (No. 372). United Kingdom: University of Hertfordshire.

Barrett, B. (2004). Return of the MPI Datatypes. Cluster World Magazine, MPI Mechanic Column, 2(6), 34–36.

Barrett, B., Squyres, J., & Lumsdaine, A. (2003, May). Integration of the LAM/MPI Environment and the PBS Scheduling System. Paper presented at the 17th Annual International Symposium on High Performance Computing Systems and Applications, Quebec, Canada.

Barrett, B., Squyres, J., & Lumsdaine, A. (2005). Implementation of Open MPI on Red Storm (No. LA-UR-05-8307). Los Alamos, NM: Los Alamos National Laboratories.

Barrett, B., Squyres, J., Lumsdaine, A., Graham, R., & Bosilca, G. (2005, September). Analysis of the Component Architecture Overhead in Open MPI. Paper presented at the 12th European PVM/MPI Users' Group meeting, Sorrento, Italy.

Blackford, L, Demmell, J., Dongarra, J., Duff, I., Hammarling, S., Heroux, M., et al. (2002). An Updated Set of Basic Linear Algebra Subprograms (BLAS). ACM Transactions on Mathematical Software, 28(2), 135–151.

Breuer, A., Gottschling, P., Gregor, D., & Lumsdaine, A. (2006, April). Effecting Parallel Graph Eigensolvers Through Library Composition. Paper presented at the Performance Optimization for High-Level Languages and Libraries (POHLL), Rhodes Island, Greece.

Castain, R., Woodall, T., Daniel, D., Squyres, J., Barrett, B., & Fagg, G. (2005, September). Open Run-Time Environment (OpenRTE): A Transparent Multi-Cluster Environment for High-Performance Computing. Paper presented at the 12th European PVM/MPI Users' Group Meeting, Sorrento, Italy.

Cheng, J., Morris, J., Tran, J., Lumsdaine, A., Giordano, N., & Pyrak-Nolte, L. (2004). Single Phase Flow in a Fracture: Micro-Model Experiments & Network Flow Simulation. International Journal of Rock Mechanics, 41(4), 687–693.

Debasis, D., Mueller, C., Chen, K., & Glazier, J. A. (2005). Solving the Advection-diffusion Equations in Biological Contexts Using the Cellular Potts Model. Physical Review E, 72(041909).

Dimov, P., Gregor, D., Järvi, J, & Powell, G. (2003). A Proposal to Add an Enhanced Binder to the Library Technical Report (No. N1455-03-0038): Information Technology Subcommittee SC22 Programming Language C++.

Friedman, D., Ghuloum, A., Siek, J., & Winebarger, L. (2003). Improving the Lazy Krivine Machine (No. 581). Bloomington, IN: Indiana University Department of Computer Science

Gabriel, E., Fagg, G., Bosilca, G., Angskun, T., Dongarra, J., Squyres, J., et al. (2004, September). Open MPI: Goals, Concept, and Design of a Next Generation MPI Implementation. Paper presented at the 11th European PVM/MPI Users' Group Meeting, Budapest, Hungary.

Garcia, R., Järvi, Lumsdaine, A., Siek, J., & Willcock, J. (2003, October). A Comparative Study of Language Support for Generic Programming. Paper presented at the Proceedings of the 2003 ACM SIGPLAN conference on Object-oriented Programming, Systems, Languages, and Applications (OOPSLA'03).

Garcia, R., Järvi, J., Lumsdaine, A., Siek, J., & Willcock, J. (2005). An Extended Comparative Study of Language Support for Generic Programming. Journal of Functional Programming.

Garcia, R., & Lumsdaine, A. (2005). MultiArray: A C++ Library for Generic Programming with Arrays. Software: Practice and Experience, 35(2), 159–188.

Garcia, R., & Lumsdaine, A. (2005, September). Type Classes Without Types. Paper presented at the 2005 Workshop on Scheme and Functional Programming.

Gerlach, J., Gottschling, P., & Der, U. (2001). A Generic C++ Framework for Parallel Mesh Based Scientific Applications. Paper presented at the 6th International Workshop on High-Level Parallel Programming Models and Supportive Environments, San Francisco, CA.

Gottschling, P. (2004). Angel–An Extensible Library for Jacobean Accumulation. Paper presented at the 4th International Conference on Automatic Differentiation, Chicago, IL.

Gottschling, P., Gaber, M., & Ralf, M. (2003, May). Numerical Simulation of Degassing Processes from Glass Powders (in German). Paper presented at the 77th Conference of German Society of Glass Technology, Leipzig, Germany.

Gottschling, P., Gräber, M., & Ralf, M. (2004). Finite Difference Calculation of Degassing from Glass Powders (in German). Paper presented at the 78th Conference of German Society of Glass Technology, Germany.

Graham, R., Woodall, T., & Squyres, J. (2005, September). Open MPI: A Flexible High Performance MPI. Paper presented at the 6th Annual International Conference on Parallel Processing and Applied Mathematics, Poznan, Poland.

Gregor, D. (2004). High-level Static Analysis for Generic Libraries. Rensselaer Polytechnic Institute.

Gregor, D. (2006). Concepts. Berlin, Germany: ANSI/ISO C++ Standard Committee, Evolution Working Group.

Gregor, D. (2006). Conceptualizing the Range-Based for Loop (No. N2049-06-0119, ISO/IEC JCT 1): Information Technology Subcommittee SC22 Programming Language C++.

Gregor, D. (2006). Large-Scale Network Analysis with the Boost Graph Libraries. Networks and Complex Systems talk series.

Gregor, D., Jarvi, J., Kulkarni, M., Lumsdaine, A., Musser, D., & Schupp, S. (2005). Generic Programming and High Performance Libraries. International Journal of Parallel Programming, 33(2).

Gregor, D., Järvi, J., Siek, J., Stroustrup, B., Dos Reis, G., & Lumsdaine, A. (2006, October). Concepts: Linguistic Support for Generic Programming in C++. Paper presented at the 2006 ACM SIGPLAN Conference on Object-Oriented Programming, Systems, Languages, and Applications (OOPSLA '06).

Gregor, D., & Lumsdaine, A. (2005, October, 2005). Lifting Sequential Graph Algorithms for Distributed-Memory Parallel Computation. Paper presented at the 2005 ACM SIGPLAN Conference on Object-oriented Programming, Systems, Languages, and Applications (OOPSLA'05).

Gregor, D., & Lumsdaine, A. (2005). The Parallel BGL: A General Library for Distributed Graph Computations. Parallel Object-Oriented Scientific Computing (POOSC).

Gregor, D., & Lumsdaine, A. (2006, February). Parallel Boost Graph Library. Paper presented at the SIAM Conference on Parallel Processing, San Francisco, CA.

Gregor, D., Powell, G., & Järvi, J. (2003). Typesafe Variable-length Function and Template Argument Lists (No. N1483-03-0066, ISO/IEC JTC 1): Information Technology Subcommittee SC22 Programming Language C++.

Gregor, D., & Schupp, S. (2002, July). Making the Usage of STL Safe. Paper presented at the Generic Programming, IFIP TC2/WG2.1 Working Conference on Generic Programming.

Gregor, D., & Schupp, S. (2003). Retaining Path-Sensitive Relations across Control-Flow Merges (No. 03–15): Rensselaer Polytechnic Institute.

Gregor, D., & Schupp, S. (2006). STLlint: Lifting Static Checking from Languages to Libraries. Software: Practice and Experience, 36, 225–254.

Gregor, D., Schupp, S., & Musser, D. (2001). Base Class Injection. Third International Conference on Generative and Component-Based Software Engineering(2186), 106–117.

Gregor, D., Schupp, S., & Musser, D. (2001). Design Patterns for Library Optimization. Paper presented at the International Conference on Parallel/High-Performance Object-Oriented Scientific Computing (POOSC'01), Tampa, FL.

Gregor, D., Schupp, S., & Musser, D. (2003). Design Patterns for Library Optimization. Scientific Programming, 11(4), 309–320.

Gregor, D., & Siek, J. (2005). Explicit Model Definitions are Necessary (No. N1798-05-0058, ISO/IEC JTC 1): Information Technology Subcommittee SC22 Programming Language C++.

Gregor, D., & Siek, J. (2005). Implementing Concepts (No. N1848-05-0108, ISO/IEC JTC 1): Information Technology Subcommittee SC22 Programming Language C++.

Gregor, D., Siek, J., Willcock, J., Järvi, J., Gardia, R., & Lumsdaine, A. (2005). Concepts for C++Ox: Revision 1 (No. N1849-05-0109, ISO/IEC JTC 1): Information Technology Subcommittee SC22 Programming Language C++.

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Acknowledgements
Projects described in this report were fully or partially funded by the following grant awards:

Lilly Endowment, Inc., Award: 1999-2280-000.
National Science Foundation Awards: ANI-0330620, ATM-0427264, CCF-0541335, DBI-0446298, EAR-0446610, IIS-0536947, OCE-0341139, OISE-0505998, SCI-0330568, SCI-0330613, SCI-0537498
National Institutes of Health Award: P20-HG003894
University of Southampton Award: GR/S90843/01
U.S. Department of Energy Awards: DE-FC02-03ER41275, DE-FC02-02ER25516,
U.S. Government Award: MDA90403C1853
Los Alamos National Lab Award: W-7405-ENG-36

Thank you
Julie Wernert, Maria Morris, Susan Quinn, Mark Long, Malinda Lingwall, Cheryl Combs, Jacqueline Whaley, Deana Forrest, Jennifer Browning, Michael Evans, Marlon Pierce, Gregory Travis

With sincere appreciation to Lilly Endowment, Inc., for its generous and ongoing commitment to Pervasive Technology Labs and Indiana University.

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